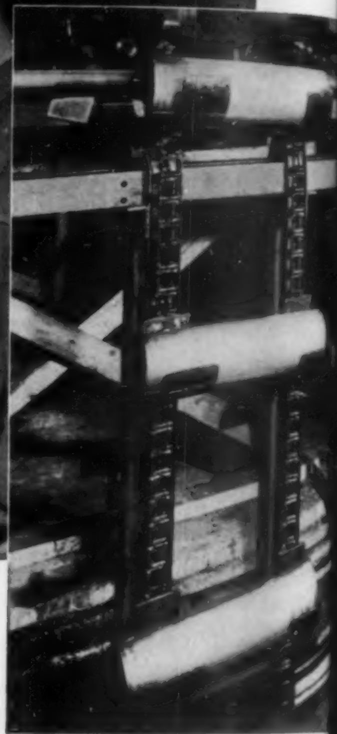
METAL PROGRESS

SEPTEMBER, 1943 VOLUME 44, NO. 3

Contents of This Issue

Here 7-in. cylinders are turned inside out and reduced to 6 in. diameter.



Cylinders, drawn to 4½-in. diame[...] in. deep through a ring die, are [...] from the press pit to the finishing

4½" x 17" Steel Cylinders–
Drawn from Inland Sheets

Only four operations are necessary to form a 4½-in. diameter by 17 in. deep cylinder that is part of a shell container used by the U. S. Navy.

In the first operation an 18-in., 19-gage, blank, cut from Inland deep drawing sheets, is formed into a cylinder 10 in. in diameter by 6 in. deep. The second operation reduces the diameter to 7 in. and increases the depth to 8⅞ in. In the third operation a 7-in. by 8⅞-in. cylinder is placed bottom end up over the lower die. The upper die, pressing against the bottom of the 7-in. cylinder, forces it into the lower die, turning the cylinder inside out while reducing the diameter to 6 in. and increasing the length to 12⅝ in. In the final operation a 6-in. cylinder is placed over the upper die which forces it through a ring die, drawing the cylinder to final size, 4½ in. in diameter by 17 in. deep.

These cylinder forming operations, like many other difficult war jobs, are proof of the uniformity and high quality of Inland flat rolled steel products—products that are being used 100% for Victory.

ARMY E NAVY

INLAND STEEL CO.

38 S. Dearborn Street, Chicago · Sales Offices: Milwaukee, Detroit, St. Paul, St. Louis, Kansas City, Cincinnati, New York

Unfortunately, Metal Progress omitted to thank, publicly, The United States Steel Corp. for the loan of the excellent engravings of a huge forging, used on the cover design last month.

CRITICAL POINTS

By THE EDITOR

FOLLOWING HARRY MCQUAID's advice — again proved most excellent — traveled 50 miles down to the south bank of the St. Lawrence from Montreal to Sorel, through prosperous looking farm lands and American villages with French names, always in view of the noble river, sister to the Mississippi and the Columbia. Sorel is worth visiting for reasons other than metallurgical, for it is in the region best known to citizens of the States for the exploits of Rogers' Rangers, extolled by KENNETH ROBERTS in "Northwest Passage". It is the site of a fort built in 1642 to defend Montreal from Indians paddling down the Iroquois River (now the Richelieu) from Lake Champlain. This early fort stood for five years, but then vanished until 1665, when Capt. PIERRE DE SAUREL was sent by the King of France to construct a new fort and town. Still standing is the 200-year-old residence of the Governor-General.... Sorel has since become an important port for grain, and now is overcrowded by workmen for a large shipyard as well as gun makers in Sorel Industries Ltd., the latter possibly unique in America as a plant building field artillery complete (except for a few minor components and rubber tires). Originally financed and built by the local family of SIMARD, who enlisted the technical aid of the great French armament firm of Schneider-Creusot, the plant was about ready to melt steel when the Maginot Line was turned and the French technical staff was forced to return home, by terms of the Franco-German armistice. At this juncture, the Canadian Government brought the Simards and the Chrysler Corp. together, activities were resumed with added impetus, and on July 1, 1941, the first 25-pounder gun rolled off the assembly line toward the battlefield.

A Canadian gun plant

RUMOR HAS IT that gun steel was made, at the start, by following a definite time-table: 4 hr. 40 min. add 1 shovel lime-coke mix; 5 hr. 05 min. sample slag, quench and smell acetylene — "Exaggerated," says ROCH GOHIER, chief metallurgist, but nevertheless necessary when starting with all new hands. One advantage, at least, is that experience gained on tonnage steels did not have to be unlearned; success is measured by such facts as that on one order for large caliber gun barrels, 35 out of 35 successfully passed acceptance tests, none being rejected in any stage of manufacture.... Steel is made in 20-ton electric furnaces, charge being own scrap, turnings, ship plate trimmings, railroad rails, heavy scrap and electrode butts to handle 5% ore. A 45-min. carbon boil is insisted on, carbon being blocked at 0.25 to 0.30% (the usual content for most ordnance forgings). A second slag is then made up for final refining and deoxidation; it is skimmed before silicon and alloys are added. Hot tops for ingot molds are carefully dried, moisture in refractories being the most common reason for "flakes". A layer of *dry* brick also covers the stool, thus delaying solidification of the bottom of the ingot and reducing the usual porosity near that region. Hot ingots are held at dull red in real "soaking pits" — tremendous rectangular ones — until a forge is ready for them.... Reduction to round for gun tube or jacket, or slab for breech block or recuperator, is done in one heat in a 2000-ton hydraulic press, unusually fast in its travel. Hot forgings are immediately buried in ashes and left there until stone cold, taking up to five weeks for the largest ones. (Furnaces are available wherein the cooling can be controlled—fairly rapid for most of the way, very slow for the lower ranges where hydrogen evolution becomes dangerous — but pit cooling in ashes is the regular practice.)

How to make electric steel

Rough machining and boring of these slowly cooled forgings is much more rapid than normalized forgings, for normalizing also promotes that inevitable banded microstructure which ordnance engineers do not like. Carbide tools have no difficulty with metal of 285 Brinell hardness. After machining, tubes are heated in vertical electric furnaces, double quenched in oil from 1650 and 1600° F., then given a rather high draw, and are ready for semi-finish machining. First, however, thick disks are removed from each end for deep etching and physical testing; most attention is given to elongation in the transverse tensile specimen, and Izod impact tests. (Preparation of specimens occupies a machine shop which almost overshadows all the laboratories, physical, chemical and metallurgical.) For a typical gun tube analysis (0.30% C, 2.25% Ni, 0.9% Cr, 0.4% Mo, 0.07% V) elongation after heat treatment would be 22% in 2 in. and Izod impact 65 ft-lb., well above the specified values. Hardness is now 250, slightly lower than the tube as forged.

Gun tube manufacture

. . . . Barrels, being machined to what are known as autofrettage dimensions, are subject to that operation. Ends are plugged and oil pumped in until the internal pressure is some 25% greater than during firing — in fact, above the steel's yield point, so the tube expands a measured amount. On relief of pressure the inner layers of metal at the bore are squeezed into compression, and so their resistance to tensile bursting forces is correspondingly increased. A low temperature anneal (750° F.) completes the operation, except that the whole cycle is repeated on naval gun forgings, including the second stress relieving. (Army gun forgings get pressure the second time but do not get the second stress relieving.) At the end the metal's yield point has increased 10,000 lb. to 130,000 psi., the tube has resisted a real "proof" test, and is enabled to endure the high pressures of modern propellent powder for a great many rounds; otherwise, the first half-dozen would ruin the breech dimensions.

Thus it would appear that the Sorel practice has about everything that is calculated to make sound forgings of large size: Furnace practice promoting clean, homogeneous steel; ingots tapered so forge reduction at breech and muzzle end is about the same; excessively slow cooling to release hydrogen; enough alloying elements for deep hardenability; violent oil quenching to give uniform martensite throughout the section without dangerous soft networks; and a high draw to get desired toughness (22% elongation, 50% reduction of area). Small wonder that harassed steel makers from south of the border make pilgrimages to Sorel to find out how the Canadians do it!

Out to the U. S. Army arsenal in Watertown, one vast machine shop making artillery, employing more men in thousands than were there in hundreds during peacetime, and found Col. Hermann Zornig's research staff housed in an elegant new building amply equipped for all sorts of studies on metal — especially in its plastic range. Some sections were studying matters of current interest: X-ray standards for steel castings; the welding of armor and ordnance steels; the erosion of gun barrels; the action of armor piercing shot. The last mentioned characterizes the specialized metallurgical studies at Watertown. As Colonel Zornig pointed out, industry is properly interested in the ability of metal to work at loads well below the elastic range, whereas important ordnance parts are expected to perform once — or at most a relatively few times — at loads *beyond* the elastic, and sometimes near the ultimate limit.

Shot and armor work in the plastic range

Important to ballistic studies is also the effect of *speed* of loading. For example, it is found that proportional limit and ultimate strength increase when tensile test pieces are pulled at increasing rates, whereas the elongation and reduction of area decrease. Where does it stop? Will we eventually reach speeds of loading where good metal fails without exhibiting any plastic movement, as ordinarily defined? Unfortunately one cannot answer the question by direct experiment for when the rate of extension goes much beyond 1 in. per in. per sec. (a speed of loading on the same order as in the breech of a gun), so much of the applied load is required to overcome inertia of the specimen that no one knows how much of the remainder is used up in breaking the metal. Consequently, the answer to any question about the performance of this, that or the other metal in a projectile's nose at the instant of impact must be found by indirection — in this way: It was discovered that lowering the temperature of the test piece affected the tensile properties in the same way as increasing the speed of loading, and an empirical equation has been found closely fitting the experimental facts. So by testing a piece while immersed in liquid nitrogen at the

Testing metal at bullet speeds

highest rate of speed for accurate results, the combined effect equals the probable action at room temperature of loading speeds approximating that existing when shot strikes armor.

TENSION TESTS at high speeds shed considerable light on the notched-bar impact test, studied at Watertown Arsenal for many years, because the rate of loading at the bottom of the notch is far greater than anything possible in a tension test. When this factor of speed is properly provided for, the relation between Charpy impact tests and the area under a stress-strain curve in tension (pointed out by H. C. MANN in *Metal Progress* for March 1935) becomes much closer. The impelling reason why ordnance engineers are so interested in this problem is that erosion in a gun barrel first shows itself as a multitude of tiny cracks in the rifling grooves, each a notch in a metal part that has to resist violent impact from exploding gas.... Another finding of the high speed tests is that any medium carbon steel which has been completely quenched to martensite and then tempered performs much better when loaded at high speed (either tension or impact) than when the identical steel is "slack quenched" to a structure of primary troostite and ferrite, and then drawn back to the same hardness and identical tensile properties (that is, when tested at slow speed in the ordinary way). The tempered martensite produces a velvety "fibrous" fracture, desired by armorers, whereas the tempered troostite breaks with a "fiery" crystalline fracture after "impact" loadings.

Erosion and heat treating of gun tubes

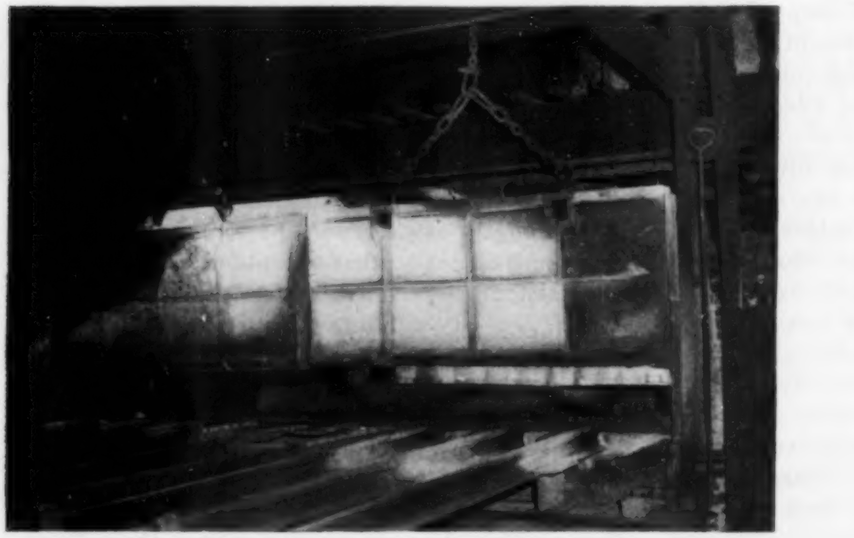
GONE, long ago gone, are the days when the draftsman marked *f* on a drawing to mean "finish", trustful that the intelligent machinist would know what to do about it. Gone with the supremacy of the engine lathe, vanished with the advent of grinders, broaches, laps and superfinishes. Ten years ago General Electric recognized the need for more definite instructions, and divided the range from smooth lap to rough flamecut into ten steps, and then made comparison blocks so that f^5 would have specific meaning to all concerned. Since before the 1914 war the U. S. Army Ordnance had marked drawings with five symbols, each representing a surface suitable for a definite application, and this convention served very well as long as the work was done in the arsenals, by workmen familiar with the inspection standards. However, in recent months, when suppliers, main contractors, subcontractors, and inspectors multiplied by the thousands, how could a common understanding be achieved? — especially since "*f*", the Ordnance symbol for "machine finish of good quality, applicable to surfaces fitting together but not moving on each other" might mean one thing to Joe Doaks, inspector at a parts manufacturer, and another thing to Elmer Zilch in the assembly line several hundred miles away. In fact *f* did mean different things to veteran gun inspectors, the smaller guns requiring a smoother *f*.

How smooth is smooth?

TO BRING some order out of this confusion, the Ordnance Department ordered its service divisions to devise a method whereby inspectors could recognize acceptable surface finishes. It was readily agreed that this involved more than "smoothness" as determined by a laboratory surface analyzer. Also that acceptable finishes could be satisfactorily shown on reference standards calibrated by such an instrument. First, about 100 samples representing each Arsenal's interpretation of *f*, *ff* and *fg* were measured optically and with a profilometer, and the results averaged for a numerical equivalent of the average depth of the tiny surface depressions (or rather their "root mean square"). This gave quantitative values for the most-used finishes, and they were modified and the scale extrapolated both ways conforming to the American Standard Association's system of preferred numbers — in geometric ratio from 8 millionths of an inch for lapped surfaces to 250 millionths for least critical mating surfaces. Next step was to prepare master specimens — flat plates about 2 by 2½ in. — and duplicates of each of these roughness standards, portions of them prepared in various ways as by milling, grinding, planing and broaching. This painstaking work was done under supervision of MARY NORTON, associate metallurgist at Watertown Arsenal. Provided with sets of these blocks, the next job was for the general committee to draw up a schedule defining *f*, *ff*, *fg* and *lap* for ordnance matériel, class by class. For example, *ff* on any drawing applying to fire control apparatus means a surface roughness equivalent to that of the standard reference block marked 125, and on any drawing applying to small caliber ammunition it means a finish equivalent to that of the block marked 63, and with these definitions any skilled inspector can check any other by visually comparing the work with the standard block and by drawing his educated fingernail across the tool marks.

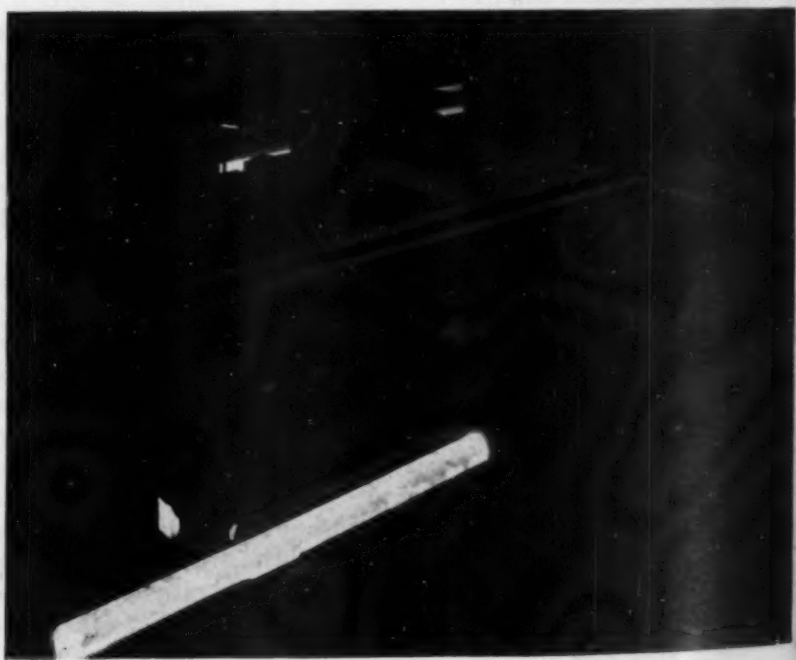
Ordnance standard finishes

Compare the method of making rough forgings for 75-mm. and 40-mm. gun tubes shown in the following photographs with the conventional method exemplified at Sorel in Canada and described on page 411. For this purpose Timken Roller Bearing Co. and its Steel and Tube Division has been able to utilize its existing steel mill, long practiced in the art of making seamless and alloy tubes not only for its own production but for sale to the power, petroleum and chemical industries. With comparatively little additional equipment, principally upsetters and heat treating furnaces, this single production line has been turning out more than 6000 roughly forged and pierced tubes every month, heat treated ready for finish machining. And they're good, passing every test imposed by U.S. Army Ordnance. No need to belabor the fact that this eliminated the need for building dozens of powerful new forging hammers and presses, and acres of gun-boring lathes, and saved time — priceless time. Lieut.-Gen. Somervell thus characterized the achievement in an address given over a year ago: "Within a few weeks, one single Amer-



1 Alloy steel of correct analysis, made to War Department specifications, is rolled into round billets of perfect soundness (surface and interior). Passing through this heating furnace, they start on their way to become the shooting end of 75-mm. guns, the basic artillery of our field army.

Photo by Aetna-Standard Engineering Co.



2 The hot billet is entering the piercing rolls; hours of machine time are saved in this method of getting the hole down the axis. Piercing the hot billet takes 15 sec. and final finishing can be done by methods similar to broaching. Former practice of drilling a solid forging, heat treated and tough, required as much as 6 hr. for this one operation.

SEAMLESS TUBE MILL PIERCES BILLETS FOR 75-MM. GUN TUBES

Pictures Released by Timken Roller Bearing Co. Captions by The Editor

ican factory using this new process will be turning out each month more heavy gun barrels than all the factories of England turned out in the whole war!" Now the story can be told in pictures.... Not least of the obvious economies is the saving of material. The pierced steel tube is not only closer to finished dimensions than a hammer-forging, but the metal

3 Operations subsequent to piercing are much like the standard practices on seamless tubes destined perhaps for oil refineries, except that the gun barrel has much thicker walls proportional to its inside diameter. In rapid succession the "plug mill" smooths the center and thins the wall slightly, and the "reeler" accurately rounds and straightens the tube, ready for the slow cooling in pits.

Photo by Aetna-Standard Engineering Co.

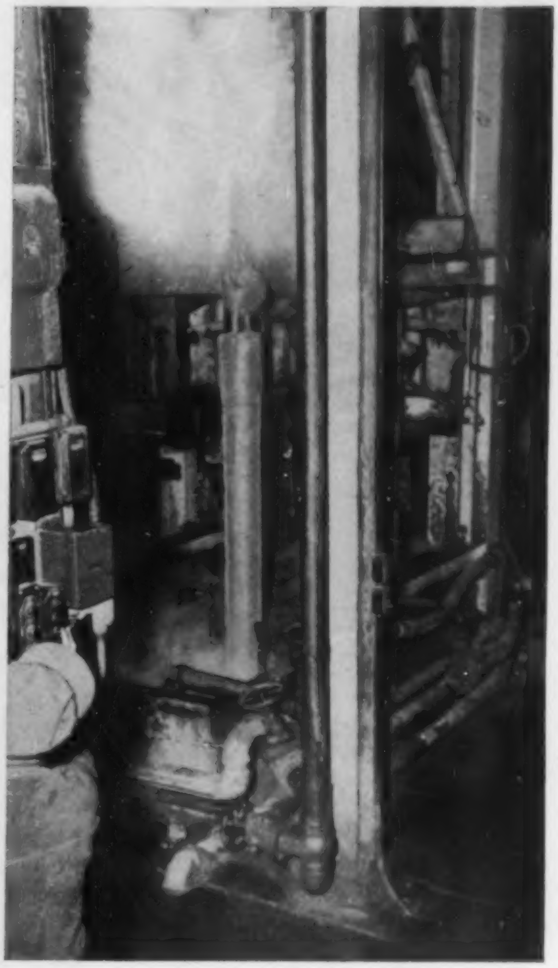
that would be cut out of the bore and returned to the mill as shavings is retained in the tube, being in truth part of the gun's wall. Metallurgists also, alive to the difficulties of casting, heating and piercing hot alloy steel, will congratulate their professional brethren at Timken for their ability to produce a thick-walled tube whose interior region is free of segregate and has the superfine qualities demanded of a rifled gun.

4 **Pierced tubes, after meticulous inspection, are heated at the end by high frequency current. A cold tube is placed in vee-blocks, induction coils in the rectangular housing are run forward, and the proper region rapidly heated — either a narrow band for throwing up a lug for muzzle rollers, or the complete breech end for general thickening by upsetting.**

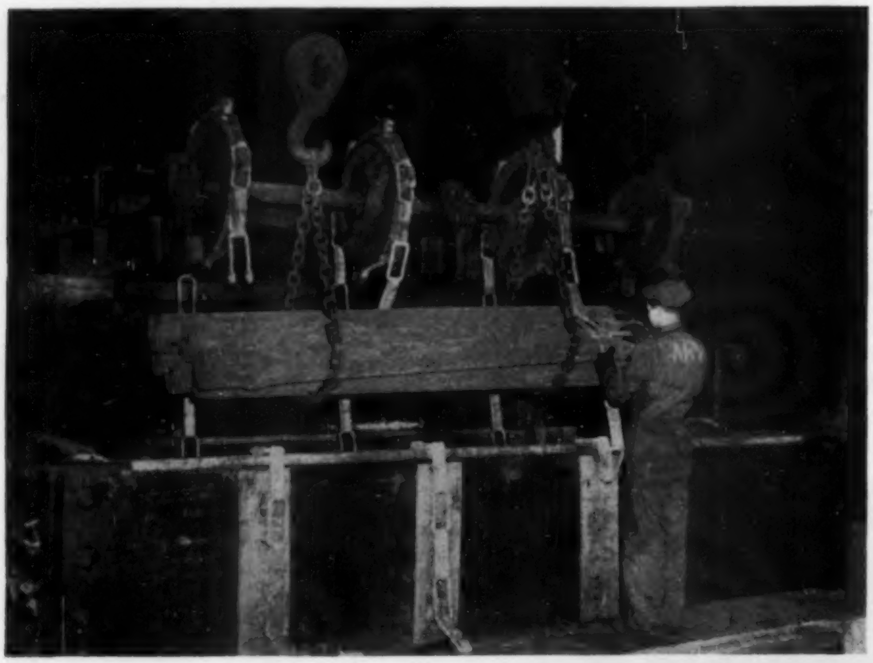
This view is looking down into one of the world's largest forging machines; dies are open and an upset tube remains in the second position. The cold shank of the tube was firmly gripped sidewise, a piercing tool entered the central hole, expanding it slightly at the same time a round die pressed against the hot end, shortening and upsetting it. **5**

Typical of American engineering are the enormous heat treating furnaces built to handle the production of upset tubes — one every seven minutes. A stirrup is butt welded to one end, the tube hung on a stout carrier, and off it goes in slow procession through high heat furnace for quenching, and low heat furnace for tempering. Strength and toughness must be adequate for service, yet hardness low enough for reasonable machinability.

6

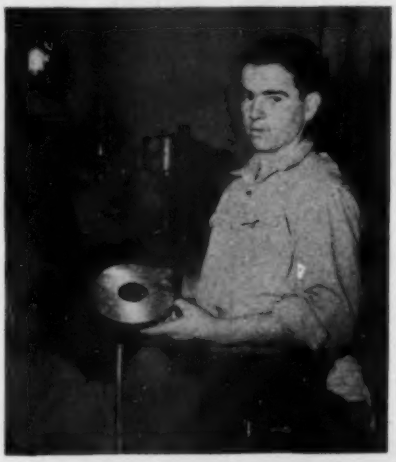


7 This 75-mm. gun tube fires its first shot — but a harmless one and out the breech end! As the hot tube was lowered into the water quench, the water-steam mixture built up high enough pressure in the muzzle to blow a cloudburst out the top.

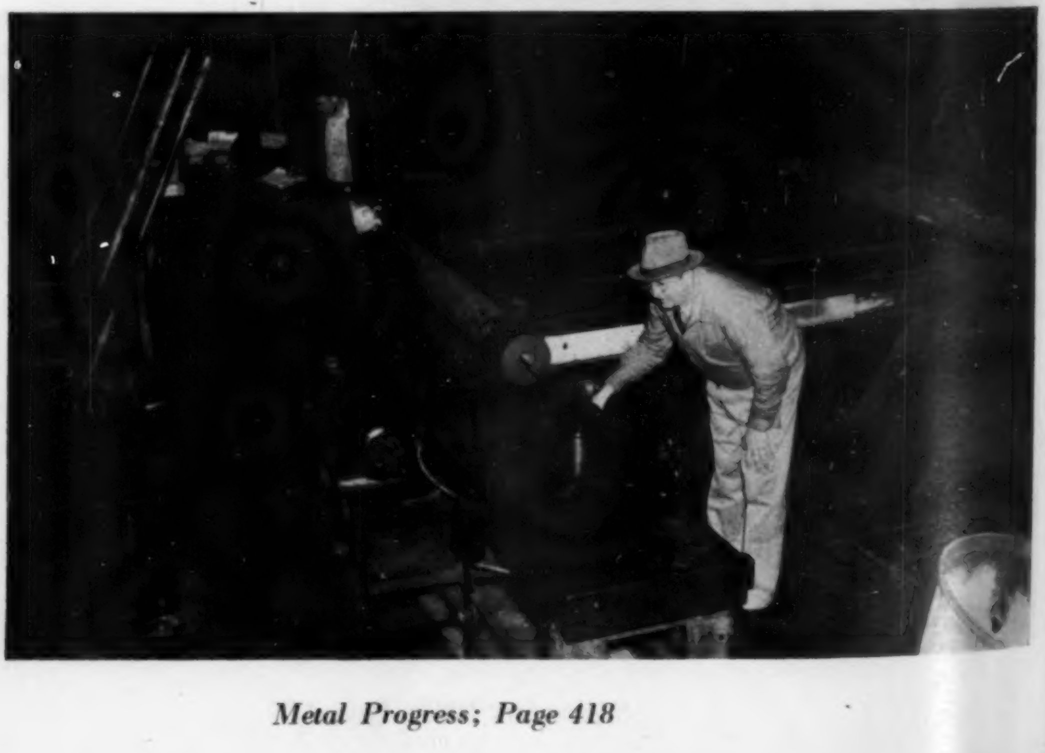


8 After heat treatment the tubes are tumbled in a pickling tank of acid to remove scale, then washed clean.

9 A disk is cut from each tube for macro-etch, to determine soundness, freedom from segregation, hardness and other characteristics as desired. Tubes are numbered serially and record kept of heat number, ingot number, position in ingot, and all chemical and metallurgical tests, so that performance in the machine shop or in service can be correlated with manufacturing practice.



10 Last operation is sawing butts off each end, bringing tube to correct length. Then the Army makes final check-up. One requirement is for accurate concentricity of inside and outside circles, and here the inspectors are gaging for alignment and out-of-round while the tube is rolled over and over in cradles.



Tubes are shipped to government arsenals and gun plants by the carload. Being close to maximum outside diameter and accurately pierced, these tubes are ideal for the gun shops. Not only is machining expedited, but the volume of light scrap returning as chips and turnings is much reduced. The surplus steel is kept near the melting shop, where it quickly joins other scrap and makes more gun barrels.

11

12

Finally, the manager of Timken's News Bureau furnishes the inevitable human interest picture ("cheese cake" to photographers) designed to show principally the finished articles — 40 and 75-mm. gun tubes — but also something of what we are fighting for and how production fits into the picture.

Buy More War Bonds and Back the Attack

D. L. Colwell and W. C. Lang showed the June 1943 meeting of the American Society for Testing Materials two standard tin cans, one as of 1939, made of 1.50-lb. hot-dip tin plate sides and ends, side seam soldered with lead-tin solder, requiring in all 4.07 lb. of tin per 1000 cans. The other can was made of 0.50-lb. electrolytic tin plate sides and bonderized steel ends, side seam soldered with lead-silver solder, requiring in all only 0.80 lb. tin per 1000 cans.

SAFE SUBSTITUTE SOLDER FOR FOOD CANS

By WAR METALLURGY COMMITTEE

Sub-Group: H. W. Gillett, E. J. Cameron, Robert F. Griggs

In 1937, out of 90,000 long tons of tin used in the United States, 20,000 tons (12,000 new tin, 8,000 secondary) went into solder. Tin plate took 39,000 tons while babbitt and bronze each took about 6,500, and collapsible tubes about 3,500. Solder ran second to tin plate, and required more than the next three major uses together. In the years 1935 to 1938, solder took 22 to 25% of the tin.

The major uses for solder were in dip-soldering automobile radiators and in soldering cans. Food cans, as a whole, required about 10% as much tin for the solder (usual analysis: 60% lead, 40% tin) as for the hot-dipped tin plate then used. The proportion of solder on cans for evaporated milk is still greater; the 1942 tin requirements for evaporated milk cans were around 5,500 long tons of tin in the tin plate and 1900 tons in the solder. The ordinary can for food, the "sanitary can", has solder only in the side seam; the ends are pressed on over a rubber-like sealing gasket. The "floated-end" can for evaporated milk, on the contrary, has both ends soldered on, and is filled through a hole in the top which is then sealed with a drop of solder. Cans are made on automatic machinery, soldering the seams at the rate of 300 to 400 cans a minute.

Long before Pearl Harbor, the Office of Production Management and the Advisory Committee on Metals and Minerals of the National Academy of Sciences (now the War Metallurgy Committee), had considered the conservation of tin in solder, and the users of tin had made preliminary studies in respect to solder in the event of a tin shortage. The can makers were in the forefront in such work, and had satisfied themselves that a 2.5% silver solder could be used on automatic lines.

A solder of this type, usually containing about ¼% copper as well as 2½% silver, had long been used by the Westinghouse Electric & Mfg. Co. where a stronger solder at high temperatures was required; this solder required a higher temperature and often a more active flux.

In those applications where only the adaptation of shop technique and the demonstration of mechanical strength were involved, there were no major barriers to the adoption of any substitute solder satisfactory on these scores.* Solder for food cans, as the can makers early pointed out, must certainly introduce no health hazards. Two types of information on this score were needed: *(a)* Does the solder dissolve in the food so as to

*Editor's Note: Emergency alternate provisions (designated as EA-B 32a) in the A.S.T.M. Tentative Specifications for Soft Solder Metal suggest six tin-lead combinations containing less tin than 30%, as well as seven other low-tin analyses containing bismuth or silver. Early in 1943 the W.P.B. issued General Preference Order M-43 limiting the tin content of general purpose solders to 21% and restricting the quantities of all tin solders that may be used.

create hazard of lead poisoning? *(b)* Do tiny droplets of solder accidentally spattered into the can during soldering have poisonous effects when swallowed? (Spatter is of rare occurrence, but the possibility has to be considered.)

Ample evidence of the lack of toxicity through solution of lead from ordinary lead-tin solder is, of course, at hand through many years' experience, and feeding experiments on rats and dogs carried out by G. R. Cowgill of the Yale University School of Medicine had shown that accidental spatter of ordinary solder was not a health hazard. Consequently the War Production Board instructed the War Metallurgy Committee to arrange for cooperative examination of both these questions of toxicity. Particular emphasis was put on evaporated milk because of the lavish use of solder in that case, and because of the importance of milk in infant feeding.

Of course, the most effective way to save tin, both in tin plate and in solder, is not to use any — as when foods are preserved by dehydration or by packing in glass, or in untinned "black plate" cans with welded side seams. A saving could be made by packing evaporated milk in "sanitary" cans. However, the existing can making and packing lines had to be used while the other facilities were being expanded. Furthermore, some foods require packing in a tinned, rather than a black plate can, and the simplest way to save tin in food cans is to use electrolytic rather than hot-dipped tin plate for the can bodies and ends, and to use a substitute solder on the side seams. Continued need for a substitute solder was therefore apparent.

After Pearl Harbor, when the tin shortage became a reality, many substitute solders were suggested other than the lead-silver combination. Much effort was put upon development of solders of low melting point, in the hope that shop technique would not have to be altered. By use of cadmium or bismuth, such low melting solders can be made with the tin content much below that of ordinary solder. Cadmium solders were barred for food use, not only because cadmium is toxic and it would take a great deal of work to demonstrate what, if any, amount of cadmium in food could be tolerated, but even more because the supply of cadmium would be inadequate. The bismuth solders were experimented with, but unless the seams were held under pressure while the solder froze, the joint would split, presumably due to the excessively long freezing range.

Hence, the only substitute solder demanding attention was the lead-silver solder. There is ample silver for industrial use.*

The Chief of the Food Division of the Federal Food and Drug Administration commented that silver could be ignored completely in regard to toxicity, so the problem resolved itself into that of lead alone. The Council on Foods of the American Medical Society has given 2 parts per million as the maximum tolerance for lead in foods, although larger amounts are found in some natural foods. The Federal Security Agency gives 0.05 gram per pound (7.14 parts per million) as the lead tolerance in fruits. Crabs are reported as containing 17 parts per million, egg yolk 2 to 10, egg white 1.2 to 4.8, and human milk 0.18.

Experiments on Canned Foods

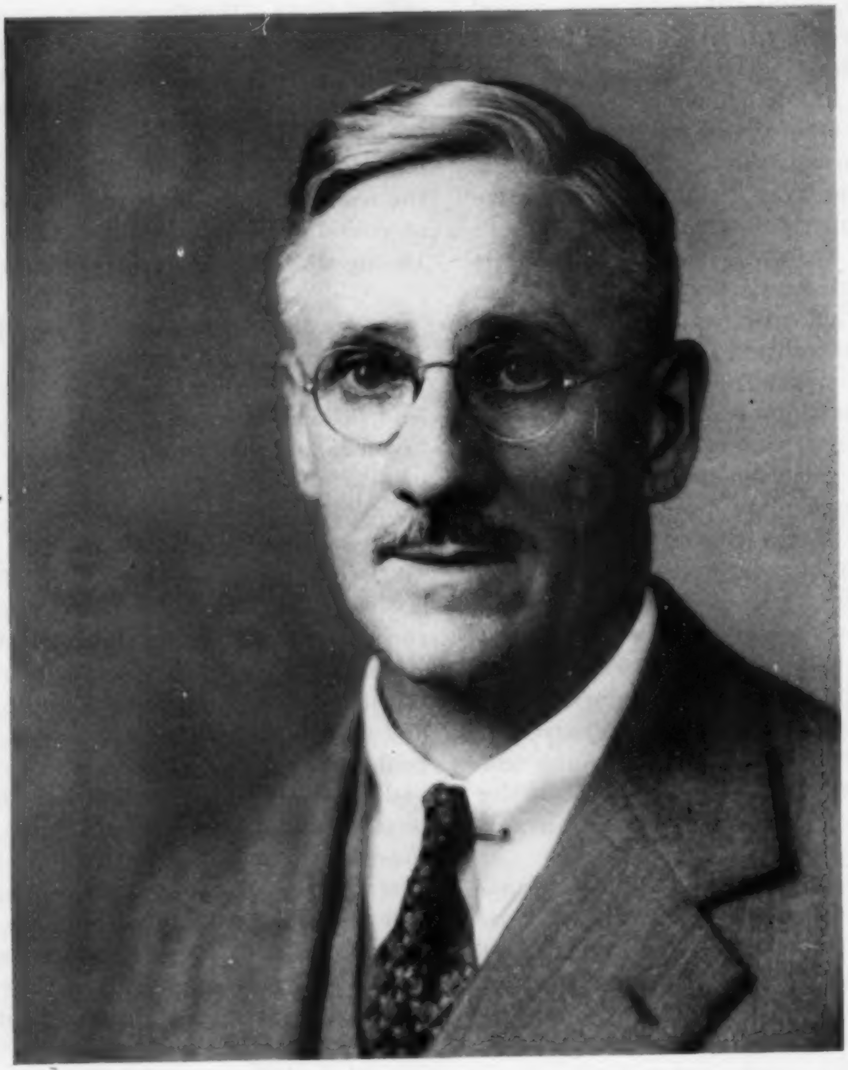
In the evaluation of permissible dissolved lead in canned foods, 2 parts per million can be taken as an upper limit for ordinary fruits, meats or vegetables. A great many different foods are canned, so it was necessary to select certain representatives for study. For this purpose, evaporated milk, orange juice, finely chopped green beans, and corned beef hamburger were chosen by the National Canners Association for storage at 98° F. These foods were processed at the usual temperatures and for the usual times, and stored in glass jars freed from lead, each jar containing a disk punched out of commercial tin plate with the edges coated with the solder to be tested. The disk was bent 180° so as to fracture the plating and expose some of the iron base. After storage, the contents were analyzed for lead and calculated back to the pick-up of lead by the contents of a No. 2 can in contact with the solder area at the side seam of a sanitary can (or the total solder area of a 14½-oz. floated-end can of evaporated milk).

The substitute solders used were 97½% lead, 2½% silver; 95% lead, 2½% tin, 2½% silver; and 93% lead, 2% silver, 5% tin. The commercial solder bath starts at about 97½% lead, 2½% silver, and in use picks up tin from the plate; it is maintained at about 3% tin and not allowed to rise above 5 or 6% tin for "hot breaks" will then occur. The 95-2½-2½ analysis represents the average commercial composition.

Nine months' storage at 98° F. — the period of test — is considered equivalent to a couple of years ordinary storage. Data were obtained for each of the solders at three-month intervals. It turns out that in none of the foods studied is there a progressive pick-up; analyses made immediately after canning *(Continued on page 454)*

*Editor's Note: The word "ample" might be questioned as of 1943; in fact this entire sentence would doubtless be rejected by those who look upon silver as a primary monetary metal.

BIOGRAPHICAL NOTES OF AMERICAN SCIENTISTS



Henry Rawdon

CHIEF METALLURGIST, BUREAU OF STANDARDS

FEW metallurgists, if any, have entered their calling by such a devious and unlikely route as Henry Rawdon, who began as an immigrant farm boy and later was six years a village school teacher before any thought of his present profession entered his head. Today he is Chief of the Division of Metallurgy of the National Bureau of Standards, and one of the most outstanding and respected members of a profession that is teeming with outstanding and respected members.

To a detached observer, there is a remarkable similarity between a metallurgists' meeting and a convocation of Presbyterian elders. In each case earnest gentlemen foregather to establish the truth and ferret out error. When schisms arise, the Presbyterians turn to an official called a Moderator — usually a man of solid learning and judgment — and abide by his decisions. When two groups of metallurgists have argued themselves to the point where they have nothing to lose but their equilibrium diagrams, they turn to Henry Rawdon, and it is only an extremely self-confident metallurgist who cares to gainsay his final judgment.

Rawdon's most noticeable characteristic is his quietness. He has a quiet voice, which he uses only in emergencies, and a quiet humor. He goes about his work with no fanfare whatever. He does not push himself into the councils of the great, and, indeed, has no need to, since they sooner or later come to him. Few of his professional associates — even those who have known him for years — have ever penetrated very far behind what he himself describes as his "slightly taciturn reserve". In a profession where conservatism is almost an occupational disease, he is an outstanding conservative. If he has an obsession it is punctuality, and all the young men under him at the Bureau who are ambitious make a point of getting there on time.

An outsider might suppose from the foregoing that Rawdon was merely a very competent automaton with no human qualities to speak of, and might be misled by the fact that he keeps a fairly tight rein on his personal reactions and tries not to inject them into his professional life. Despite his best efforts at monastic withdrawal, however, and for reasons as recondite as metallurgy itself, Rawdon enjoys a degree of personal respect and affection that is rarely equalled. When pinned down to a reason for this feeling, his confrères are sometimes surprised — but never concerned — at not being immediately able to put a finger on the characteristic that they admire. He has none of the tricks or mannerisms that are commonly associated with "personality", and it has apparently never occurred to him to produce that front of synthetic "good fellowship" that so many men feel is necessary for social or business success. His success, both as a person and as a scientist, is, in short, a triumph of character.

HENRY RAWDON was born in the early 1880's in Derby, England, and is descended from a long line of English farmers. His maternal grandfather, whose name was Buxton, was a portrait painter of considerable note. Henry's family came to America when he was four, and joined relatives in Michigan. There he grew up and went to school; he considers himself being practically native born. His childhood and adolescence were spent in a small village and on a farm, and his education was fostered in the ungraded "district schools".

By assiduous home-study he passed the examination for country teacher at seventeen, the minimum age, but such jobs were rich plums and difficult to obtain for such a youngster, so he enrolled at the Michigan State Normal College at Ypsilanti. He paid his way through four years at Normal School by various part-time jobs, including farm work during the summer vacations, and emerged in 1903 with a life certificate in teaching. He had specialized in chemistry and biology. There followed six years of teaching in the high school at Marlette, Michigan; three as a science teacher and three as superintendent. He then decided to do further work in chemistry and make it his career. His decision to abandon teaching was bolstered by the fact that, as he puts it, "At that time educational work as a career was lacking in the security of position that it enjoys today." In 1909, then, he entered the College of Engineering of the University of Michigan.

At Michigan, metallurgy was just being introduced as a part of chemical engineering, and he thus became aware of the complexities of iron and steel, a subject which has engrossed him ever since. His interest in these metals was stimulated by his close association with Professor Edward DeMille Campbell, the blind metallurgist the delights to honor, whose personal assistant he was during his senior year. As further evidence of his scholarship, Rawdon was elected to the honorary chemical, engineering, and scientific societies. He had just begun some graduate work in 1912, when the chance came to enter the pioneering field of metallography in the newly formed Division of Metallurgy at the Bureau of Standards. It was too good an oppor-

tunity to turn down, and so, in 1912, he moved to the Bureau and has remained there ever since in various positions of increasing responsibility. He became chief of the Division of Metallurgy in 1929.

Henry Rawdon's interest in the structure of metals came about, he says, as a natural consequence of his earlier training with the biological microscope. He has been particularly concerned with showing how the crystalline structure relates to and determines the useful properties of metals. Among other things, he has also investigated the corrosion of metals and the measures necessary to prevent or alleviate it. In this field he published one of the pioneering books, called "Protective Metallic Coatings".

He is a member of many years standing in the American Society for Metals, The American Institute of Mining and Metallurgical Engineers, and the American Society for Testing Materials, and has served on many of their committees. At the Bureau of Standards he is involved in a multitude of activities connected with the war effort, being a member of numerous committees and boards, advisory to the War and Navy Departments, the War Production Board, the National Research Council, and so on . . . . .

Henry Rawdon is a family man in the good, old-fashioned sense. That is, when he is through work he goes home for his relaxation and social life, rather than to a golf course or a movie. Home is in the country, 15 miles outside of Washington, originally an open field, but transformed by Rawdonesque hard work into a beautiful little estate. He doesn't care for sports and gets all of his exercise working on his place or digging in his garden. Right across the road is a golf club, and for years he has watched its members expensively taking their exercise, but he has never crossed the road to join them. Every morning he works in his garden or does some little job about the place before breakfast, and in the winter he walks through the woods with his dog. Apparently this is what the doctor ordered, for in more than 30 years at the Bureau of Standards he has been on sick leave three weeks.

Even after all these years in Washington Rawdon still considers himself a Michigander, and has always maintained his voting residence there. Rather inconsistently he married in 1917 a girl from Maryland instead of one from Michigan, Emily White Saunders, but she has made up for her ill-advised selection of a birthplace by sharing his love of the country, and by creating the home that means so much to him. They have two children, a son Richard Henry who is in the Army Air Corps, and a daughter Emily who now does chemical war work.

There is good evidence that Mrs. Rawdon — like wives everywhere — is his severest critic as well as his best friend. An acquaintance recently chided Rawdon for being too unassuming. He admitted that he probably was, and added, in his thoughtful way, "Too unassuming for my own good, I guess — at least, so I've often been told."

EDWARD C. MCDOWELL, JR.

MECHANICAL PROPERTIES OF METAL FOILS*

By Bruce Chalmers and P. W. Seddon

THE only mechanical properties of foils that appear to have any practical significance are those which determine the behavior of the material under tension and flexure. To investigate these properties, however, new techniques and apparatus had to be developed.

Tensile Testing Instrument: For tensile testing the specimen is strained at a constant rate, the load being measured by an electromagnetic dynamometer mounted in series with the specimen on a framework so it can be moved vertically at constant speed and transmit a corresponding strain to the specimen. The dynamometer consists of a steel diaphragm whose distance from a U-shaped core (of the 4% silicon steel of high magnetic permeability known as Stalloy) is altered by its flexure under the imposed load, and the change in the electrical balance is measured by a galvanometer. The specimen is shaped like the cross section of an I-beam, with particularly wide flanges, and these "flanged" ends are held by jaws supported on knife edges and steel balls so that the two edges

(Continued on page 456)

*Abstracted from *Journal* of the British Institute of Metals, Vol. 68, 1942, p. 283.

The author, who was connected with W.P.B. during the days when steps had to be taken to conserve our strategic alloying elements, speaks with authority concerning the necessities of that situation. Long experience as a toolsteel maker and tool user also gives him a good view of what can be done in the shops to get the most out of the tools and toolsteels that are available.

THE ROLE OF TOOLSTEEL IN THE WAR EFFORT

By SAM C. SPALDING

Metallurgical Engineer, The American Brass Co., Waterbury, Conn.

TOOLSTEEL in early times was simply a carbon steel with carbon in the higher brackets and no other alloying constituents except nominal percentages of silicon and manganese. It was usually made in crucibles and graded for various uses by ranges of carbon, more commonly known as "tempers". That, of course, was prior to the turn of the century, as in more recent times, the term toolsteel means high speed steels and all kinds of complex, highly alloyed steels for hot and cold working operations, as well as the plain carbon steels. In fact, during the past 25 years, it would seem that metallurgists, in order to keep in line with our general speed-up in production and the automatic machine age, had vied with one another to add more alloy and alloy in greater variety to the common toolsteels, as though the aim was to produce a special alloyed steel for each individual purpose. The impact of the war in Europe, although it was not immediately recognized, threw this viewpoint out of gear by gradually developing shortages of the alloys we were now so accustomed to in our toolsteels.

As the war went on into its second and third year, bringing with it also our entry into the war, the limited availability of many of the steel making alloys became more and more apparent. As the toolsteels other than the plain carbon are dependent on alloys for their special properties, they soon began to feel the pinch. In common with many other commodities, all steels had to be surveyed, and a course charted for the future, the aim being to cover the needs of the tool-using industries with the least expenditure of alloys. As we considered the efficiency of our alloy additions it was evident that the maxim "If some alloy is good, more is better" had often been the criterion rather than "What is the minimum alloy required to give the necessary properties?" The toolsteel business has always been highly competitive, and to gain a foothold in a desirable account, a new or more highly alloyed steel was frequently brought out. In normal times this is no doubt a good method, and keeps an industry alive and healthy as, in the long run, the new steel either finds its place by displacing the older one or fades from the scene. The industry was quick to recognize that such conditions were not compatible with the maximum war effort, and the first step was a voluntary reduction by producers in types and brands which often overlapped in function. This immediately resulted in a saving of alloys and, by the concentration on fewer varieties, increased production.

Revision of the List

The principal alloys used in toolsteels that became critical in supply, and the order in which their scarcity became apparent, were tungsten, vanadium, nickel, and molybdenum. There was a brief fear of a cobalt shortage, which happily was relieved before serious curtailment in the toolsteel field had to be made.

Fortunately, in respect to tungsten, we had a substitute steel pretty well along the road of development, in the form of the so-called "moly high speed steels". I don't know when we could set the date that they were first brought into commercial use, but by 1935 their use was considerable and increasing year by year. When the necessity of conserving our tungsten supplies became evident, and the M-14 order was issued (June 11, 1941), the ground work had been well laid and the change over to the use of a larger proportion of molybdenum high speed steel was readily accomplished. The M-14 order, as originally issued, called for a 50-50 division — in other words, no more than 50% of a user's requirements could be filled with the tungsten high speed steel, which now became known as "Type B steel", and the balance must be of the molybdenum type, known as "Type A steel". This order was to expire on November 30, 1941.

Experience gained in the use of the Type A molybdenum steels under this order was sufficiently favorable, and the tungsten shortage became more stringent, so an amendment to the M-14 order was issued on November 29, 1941, permitting only 25% of Type B or tungsten steel in making up a person's high speed steel requirements. This restriction was in effect until May 10, 1942, when the order which is now known as M-21H appeared, the old M-14 having been revoked. The new regulations permit 35% of tungsten steel with 65% of molybdenum steel. This change was made to help ease the load on molybdenum and was made possible by a somewhat increased supply of available tungsten.

With the acceleration in production that came after Pearl Harbor and our entry into the war, it soon became evident that a critical shortage existed in vanadium. While this element was used quite generally, when the necessity for economy came it was decided to eliminate it from all toolsteels other than high speed, and to eliminate the so-called "double vanadium high speed steels", except those containing cobalt. This was followed later by a definite limitation of the vanadium content of all high speed steels to the absolute minimum required for a satisfactory cutting tool.

As the war production program moved on through the year 1942, it developed that the measures to conserve nickel in alloy steels and tungsten in high speed steels, together with the greatly increased production of all steels, were throwing a very heavy burden on molybdenum, which in turn became a critically short alloy. To help bring consumption within acceptable bounds, toolsteel was asked to make its contribution to conservation. This was immediately undertaken and accomplished by limiting the amount of molybdenum in alloy toolsteels to the absolute minimum required. For example, the quantity of the high molybdenum types of high speed (containing 7.5 to 9% Mo) which could be produced in any three months was limited to 30% of that produced in the second quarter of 1942. The balance of 70% of the make was to be of the so-called 6-6 type (which was actually set up on 5½-4½ basis, with maximum molybdenum set at 5%). The remaining alloy toolsteels, consisting of the general classes of hot work steels, high carbon high chromium, air hardening die steels, and the miscellaneous alloy toolsteels, were then carefully studied by cooperating groups of metallurgists from industry and the War Production Board, and the alloy contents and the varieties of each type were cut to the absolute minimum of good practice.

This covers briefly, and in more or less chronological order, the various steps taken to get the maximum production of suitable toolsteel with the minimum expenditure of critical alloys. I have made up the adjoining table which represents a fairly complete though condensed list of the grades of toolsteels in common American use prior to 1940. Probably we can best illustrate what changes have been made due to the present emergency, by showing how this list has been modified into steels at present available. Actually, compared to the changes forced upon other fields, the changes have been very minor in character.

Changes in Specific Steels

Changes in detail are as follows:

No. 1, plain carbon toolsteel. No change.

No. 2, carbon-vanadium steel. Eliminate the vanadium, which eliminates the steel.

No. 3, tungsten hot work. Eliminate the vanadium.

No. 4, molybdenum hot work. Eliminate the vanadium and set a maximum of 1.50% on molybdenum.

No. 5, chromium hot work. Set maximum of 0.50% on molybdenum.

No. 6, tool room oil hardening. Eliminate vanadium and set a maximum of 0.30% on molybdenum.

No. 7, tungsten fast finishing steel. No change.

No. 8, medium tungsten toolsteel. Eliminate the vanadium and set a maximum of 0.30% on molybdenum.

No. 9, carbon-chromium steel. Eliminate vanadium and set a maximum of 0.50% on molybdenum.

No. 10, chromium-tungsten. Eliminate the vanadium.

No. 11, chromium-vanadium. Eliminate vanadium, which eliminates the steel.

No. 12, chromium-nickel toolsteel. Eliminate the molybdenum and limit nickel to 1.75% max.

No. 13, silicon-manganese toolsteel. Limit molybdenum to 0.50% max.

No. 14, high carbon chromium. Eliminate the vanadium and limit molybdenum to 1.0% max.

No. 15, chromium air hardening. Eliminate vanadium and limit molybdenum to 1.25% max.

No. 16, 18-4-1. Limit vanadium to 1.10% max.

No. 17, 18-4-2. Eliminated entirely.

No. 18, molybdenum high speed. Limit vanadium to 1.20% and molybdenum to 8.75%.

No. 19, molybdenum high speed. Limit vanadium to 1.90% and molybdenum to 8.75%.

No. 20, molybdenum high speed. Limit vanadium to 1.60%, molybdenum to 5% and tungsten to 6%.

No. 21, cobalt high speeds. Limit vanadium to 1.90% max.

From the above it is apparent that the main effort was to conserve vanadium, this element being eliminated from all types except the high speed steels, where it has definite effect on the cutting efficiency of the steel.

Carbon steel, sometimes called plain carbon toolsteel, or just toolsteel, is *the* toolsteel of industry. It is by far the most widely used and most adaptable for a wide variety of purposes (except machine cutting tools, where high speed or carbide tools are pre-eminent). Some of the reasons why it is so widely adaptable are that by suitable variations of carbon and hardening treatment, we can go from the machine steels up to the maximum range of hardness. In the higher carbons it hardens file-hard after a simple water quench, yet (due to the fact that the depth of hardening is definitely limited, and the hard surface is backed up by a softer, tougher core) it has a resilience and ability to absorb shocks not possessed by many of the more expensive alloy steels. It can be worked over and rehardened a number of times without harmful results. Forging and hardening are relatively simple.

In other words, carbon steel couples the best all-around properties with ease of handling. Under a war shortage of alloying elements, its place in the tool room becomes most important, and its wider use means real conservation.

In addition to the steps cited, which had to do with the production of toolsteel, it was also recognized that conservation could be accomplished from other angles.

Table I — Changes in Representative Types of American Toolsteels as of 1940

Italic type means steels or elements eliminated by W.P.B. conservation orders in 1942; **bold face type** means maximum permissible content at present.

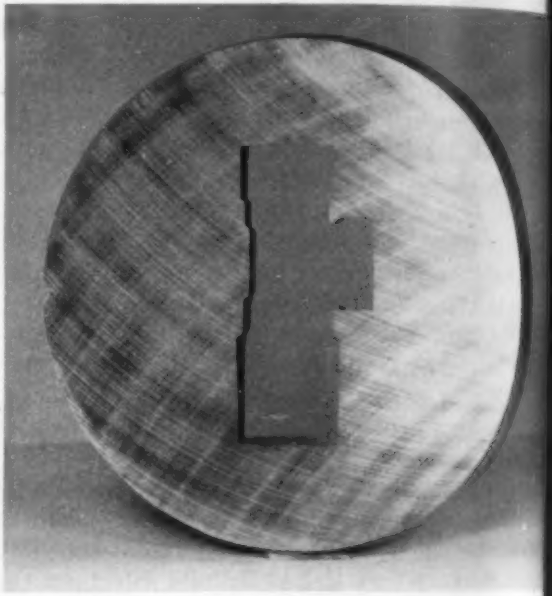
No.	Type	C	Mn	Si	Cr	V	Mo	Others
		Carbon Toolsteels						
1	Plain carbon	0.70 to 1.3	0.25	0.25				
2	*Carbon-vanadium*	*0.70 to 1.3*	*0.25*	*0.25*		*0.20*		
		Alloy Toolsteels						
3	Tungsten hot work	0.25 to 0.55	0.30	0.30	3.0	*0.50 to 1.0*		5.0 to 18.0 W
4	Molybdenum hot work	0.25 to 0.45	0.30	1.00	5.0	*0.25*	1.0 to 1.5	1.5 max. W
5	Chromium hot work	0.75 to 1.10	0.30	0.30	3.0 to 4.5		**0.50 max.**	
6	Tool room oil hardening	0.70 to 1.00	1.0 to 1.8	0.30	0.50 max.	*0.20 max.*	**0.30 max.**	0.50 max. W
7	Tungsten finishing	1.20 to 1.50	0.30	0.30	0.50			3.0 to 5.0 W
8	Medium tungsten	1.00 to 1.30	0.30	0.30	0.50	*0.25*	**0.30 max.**	1.25 W
9	Carbon-chromium	0.80 to 1.20	0.40	0.30	0.50 to 1.80	*0.25*	**0.50 max.**	
10	Chromium-tungsten	0.45 to 0.60	0.40	0.30	1.5	*0.25*		2.5 W
11	*Chromium-vanadium*	*0.45 to 0.60*	*0.40*	*0.30*	*1.0*	*0.20*		
12	Chromium-nickel	0.60 to 0.80	0.40	0.30	0.85		*0.50 max.*	**1.75 Ni max.**
13	Silicon-manganese	0.40 to 0.70	0.80	2.0	0.50 max.		**0.50 max.**	
14	High carbon chromium	1.50 to 2.20	0.40	0.40	10.0 to 14.0	*0.40*	**1.0 max.**	3.5 max. Co
15	Chromium air hardening	1.00	0.70	0.30	5.0	*0.30*	**1.25 max.**	
		High Speed Toolsteels						
16	18-4-1	0.70	0.30	0.30	4.0	**1.10 max.**		18.0 W
17	*18-4-2*	*0.80*	*0.30*	*0.30*	*4.0*	*1.8 to 2.5*		*14 to 20 W*
18	Molybdenum high speed	0.80	0.30	0.30	4.0	1.25 (**1.20**)	8.25 (**8.75**)	1.3 W
19	Molybdenum high speed	0.80	0.30	0.30	4.0	2.25 (**1.90**)	8.25 (**8.75**)	
20	Molybdenum high speed	0.80	0.30	0.30	4.0	1.75 (**1.60**)	4.5 (**5.0**)	5.5 W (**6.0 W**)
21	Cobalt high speeds	Any of above plus cobalt over 3.5 min.				**1.90 max.**		3.5 min. Co

One was the more efficient and careful use of tools. In other words, anything which could be done to reduce the breakage or spoilage of tools meant less tools required and in turn less toolsteel for their manufacture. This idea was stressed by advertisements, articles in trade journals, films gotten up by various companies showing methods of more efficient preparation and use of tools, and educational programs in the shops for the machine operators. The latter involves such things as the proper application of chip breakers, the danger of jamming tools up against the work, properly making sure everything is tight before starting an operation, having tools reground by an experienced tool grinding department instead of the individual workman — all steps which become so much more necessary with the large proportion of new, inexperienced help.

Another field which has been worked to advantage is the "tipping" of tools. This can be viewed in two ways — first as a method of making new tools, and second as a method of salvaging tools where worn out tools are used as tips for new ones. There are several ways of accomplishing this, as by cementing, welding or brazing. Worn out or broken tools can also be salvaged by butt-welding short ends together to make new tools or to repair broken ones. In fact, a number of companies have demonstrated that amazing savings of high speed steel can be accomplished by establishing a salvage department in each plant, to take these problems in hand.

Another very profitable method of salvage is the regrinding of worn out tools. Cutters, saws, taps, files, and the like, which are worn down below the point of usefulness, may be brought back to duplicate their original form by expert grinding with special wheels shaped for the job. Perhaps they may be given a different form. Such salvage is done by straight grinding; no annealing or rehardening is necessary.

Hard chromium plating is used in a different way to prolong the life of tools. In many instances the original tool is plated to get longer initial life. By replating the worn surfaces the useful life is prolonged, often by repeated runs. If the tool itself is not damaged, it can be replated as it becomes worn and run again and again. This

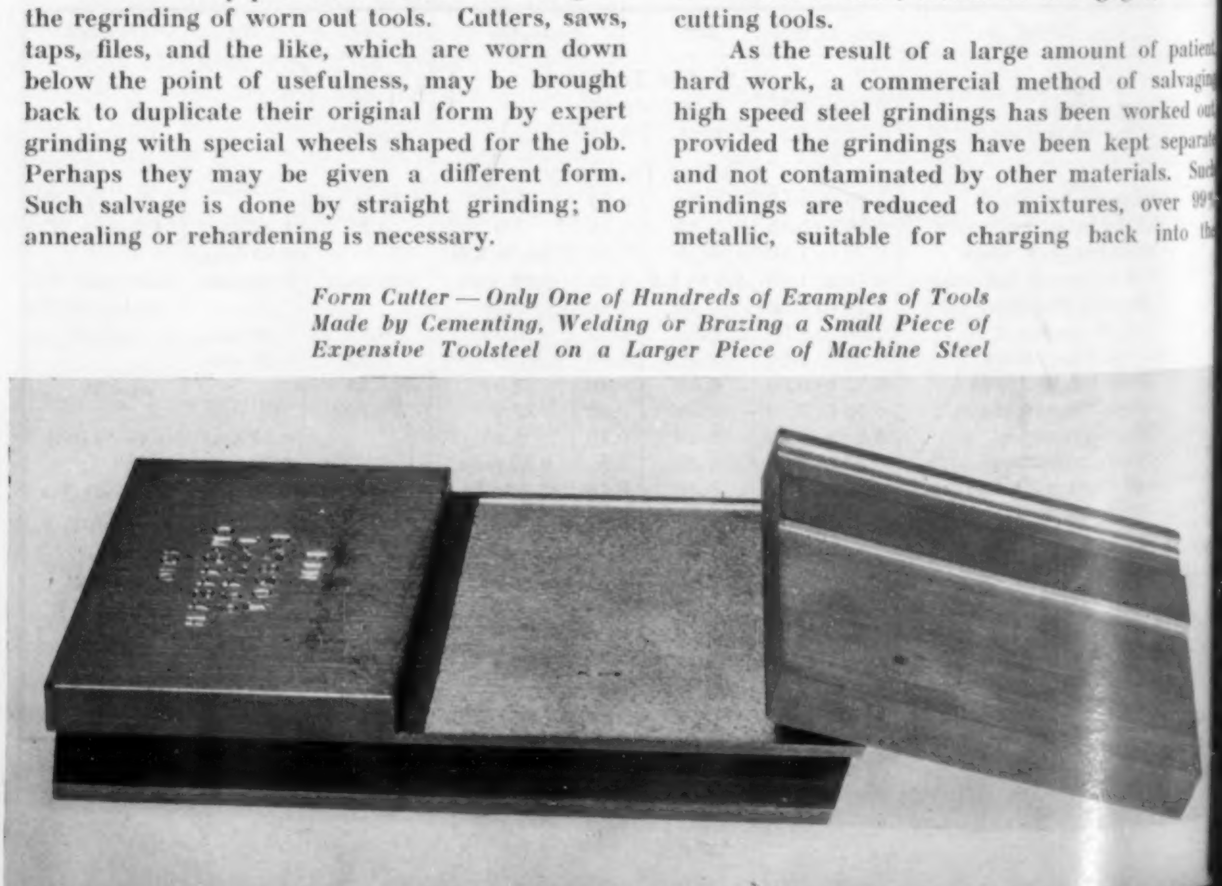


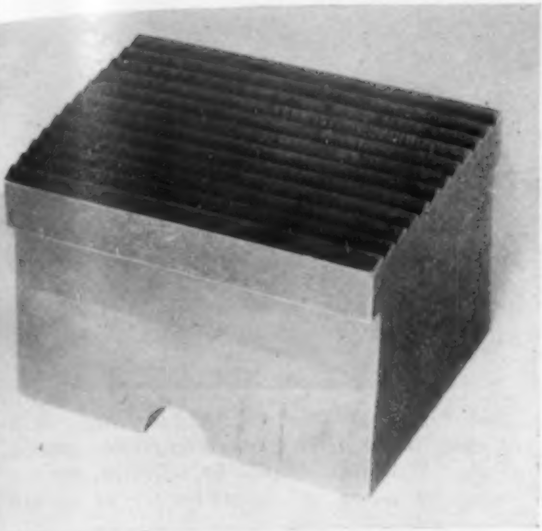
Well Proportioned Trimming Die, Where Carbon Toolsteel, Water Hardened, Gives Required Safety in Manufacture and Use

method is more frequently applied to wearing tools such as dies, mandrels and gages, than to cutting tools.

As the result of a large amount of patient hard work, a commercial method of salvaging high speed steel grindings has been worked out provided the grindings have been kept separate and not contaminated by other materials. Such grindings are reduced to mixtures, over 99% metallic, suitable for charging back into the

Form Cutter — Only One of Hundreds of Examples of Tools Made by Cementing, Welding or Brazing a Small Piece of Expensive Toolsteel on a Larger Piece of Machine Steel





A Problem in the Selection of Steel — Solved by Medium Carbon, Alloy Toolsteel, Possessing Toughness With Moderate Hardness

elting furnace. This, of ourse, means alloy conervation — the grindings ecome a high grade ore of ungsten, molybdenum, hromium and vanadium.

Better Design

Another thing which e do not think can be overmphasized at this time is he importance of preservng and getting the best posible life out of our tools. his is not altogether a unction of steel analysis nd hardening. Design plays most important part; ctually, more can be done y so designing the tool as to eliminate or minimize weak points to insure long life, than by uggling the steel analysis and its treatment.

Too many times we see tools designed from mechanical standpoint only, with no consideraion given to the metallurgical aspect of the probem. It is well recognized that when stress is pplied to a body, symmetrical in section, the pplied load tends to distribute itself evenly hroughout the body being stressed. If, however, he body is not symmetrical, and contains sharp ngles, abrupt changes of section or keyways, the tresses tend to build up to high values at these ocalized points. Recent articles in *Metal Progress* mphasize this feature as it relates to the service ife of machine parts, and the same principles apply to tools. Other published analyses of the effect of a notch on a plain cylindrical piece when subjected to tensional stresses are of interest in this connection; the stress in tension is multiplied two or three times its original value at the base of the notch, depending on its shape at the root. Bear in mind that this is simple static tension, and does not include impact and all the other dynamic stresses which a tool experiences in service.

Surface finish has also an important bearing on the life of cutting edges. A roughly finished cutting edge is made up of a series of projections easily broken off, thus dulling the tool. A smooth finished cutting edge prolongs tool life. This emphasizes the importance of honing cutting tools. A rough quantitative appraisal of this factor is contained in tests by Faulhaber on the effect of finish on the endurance limit of standard laboratory specimens in the fatigue test:

Type Finish	Per Cent of Endurance
Polished	100%
Ground	92
Smooth turned	83
Rough turned	80
Depth of notch	
0.004 in.	75
0.020	59
0.080	58

Petersen has also shown that keyways ⅛ in. deep by ¼ in. wide have a pronounced influence on the endurance of specimens 1 in. diameter. Such a keyway made with "sled runner ends" cut the endurance limit to 62%; another with regular rounded ends cut it to 48% of a smooth

Tool Where Fillets and Chamfers Are Ample, so Plain Water-Hardening Steel Can Be Satisfactorily Used

Small Bosses on Ends Must Be Protected in Hardening to Prevent Breaking in Water Quench, When Made of Carbon Toolsteel

specimen. His study on the effect of transverse holes is equally suggestive. A ¼-in. hole in a 1-in. specimen reduced the endurance limit to 71%; a $\frac{3}{16}$-in. hole in a 3-in. specimen reduced the endurance limit to 53%.

The effects of threads are illustrated by the findings of Stanton and Barstow, who showed that screw threads on a specimen subjected to repeated stress reduced the endurance limit to 67% of what it should be, reckoned on the area at the bottom of the thread.

All of the above figures are on medium carbon alloy steels and would be much accentuated in the case of hardened toolsteels.

As, of necessity, many tools must contain some or all of these deleterious features, we must by generous fillets, radii, chamfers, and so forth, do all we can in design to mitigate their effect and, of course, so design our tools as to eliminate these weak points. We must not let ourselves be deluded by the thought that because a tool in use is not subject to shocks or impact stress we can avoid these precautions. Most tools have to be hardened, and in the hardening operation itself they are often subjected to greater stress and shock than they may ever be in use. I feel perfectly safe in making the statement that the majority of tools and parts which break in use or in the hardening operation are casualties because of neglect by the designer or mechanic who omits proper fillets or radii at sharp corners.

Sad Plight of Tool (With Thin Rims on a Heavy Body) After Quenching at Too Rapid a Rate. If design cannot be adjusted, the tool must be made of an air-hardening analysis

Another important point is to avoid attaching small sections to large ones unless it can be done by gradual tapers or long radii. If you visualize the volume changes which occur during hardening, you can see why heavy stresses are set up which are localized at the point of attachment of the small section; if the change of section there is abrupt, it will probably fly off.

Usually the last operation on a set of tools before delivery to the shop ready for use is to grind them. Many a perfectly designed and hardened tool has been spoiled in grinding. In the first place, the proper wheel speeds and feeds should be selected by experience and consultation with experts of the grinding wheel manufacturers. Improper grinding can both soften and crack hardened tools. Gerald R. Brophy has given the results of some investigations on this subject in a paper before the American Society for Steel Treating (●) entitled "Stresses and Cracks in Hardened and Ground Steel" (see *Transactions*, Vol. 18, 1930, p. 423). All tool room foremen, tool hardeners, and metallurgists should study it carefully. Brophy's findings confirm those of practice in a very definite way — namely, that with improper grinding conditions, any hardened tool can be cracked and ruined, that tools overheated in hardening are more susceptible to cracking than those properly hardened, and that proper drawing or tempering lessens the susceptibility to cracking.

Bad Case of Alligator Cracking on Large Punch Due to Unbelievably Bad Grinding Practice

In closing this brief paper on toolsteels and the war effort, I would like to add a word of tribute to the toolsteel producers. They have, in all cases, been most co-operative. Though called on many times on very short notice to make sudden and often drastic changes in schedules and practice, sometimes counter to long-established promotional and sales campaigns, the industry has never hesitated. Without this ready and helpful co-operation, the road would have been a long one, and nothing like comparable results could have been accomplished. ●

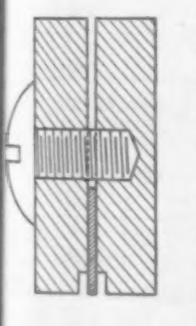
BITS AND PIECES

METALLURGICUS' OWN DEPARTMENT

(An ⊕ book of your choice for a publishable item)

Improved Clamp for Sheet Metal Specimens

IN PREPARING sheet metal for metallographic examination, a metal clamp is frequently used to hold the specimen. Unfortunately, difficulty is often encountered in etching specimens mounted in this way, because etchant is retained between the clamp jaws and the specimen, and seeps out later to stain the polished surface. Cellophane and soft metals have been recommended for gaskets to seal the crack, but the former is somewhat sloppy to use and the latter introduces galvanic difficulties during etching; neither method prevents seepage of corrosive out from around the ends of the specimen.



A simple way to overcome these difficulties is to relieve the jaws of the clamp so they do not come into contact with the polished surface, as shown in the small engraving at left. This is easily done by closing the clamp and making a groove $\frac{3}{32}$ to $\frac{1}{8}$ in. wide and about the same depth, along the line of contact between the jaws, with an abrasive cut-off wheel or hack saw.

Sheet metal as thin as 0.012 in. has been successfully polished in such a clamp with slightly relieved jaws. In polishing long specimens like this, there is less danger of rocking and rounding the edges if the long dimension is held parallel to the direction of travel of the abrasive paper, instead of turning through 90° after each stage of polishing, as is more or less standard practice. (J. E. BURKE, Research Laboratories, Norton Company.)

Quenching Fixture for Small Items

WHEN necessary to harden locally a large number of small screws (or any small part with a flat end) I use an ordinary magnet. The parts are arranged on the magnet, placed in the lead pot to the proper depth, quenched and removed. This method is adaptable to a wide variety of jobs which are time-consuming yet do not warrant the making of special fixtures. (BERNARD ZYNIEWSKI, Tool Hardener, Watervliet Arsenal.)

Chart for Computing Tensile Stress

THE LABORATORY WORKER who pulls unmachined test bars — as of cast non-ferrous metals — often has quite a computation to determine the results, due to the variation in diameters of the test bars. This computation of pounds per square inch (psi.) from the breaking load (or yield load) and area looks simple, being

$$\text{Psi.} = \frac{\text{Load}}{\pi\left(\frac{d}{2}\right)^2}$$

but a nomographic chart is helpful for speed and accuracy. This type of chart is one of the simplest to construct and may be drawn in a short time to cover any desired range. The larger the chart the better the accuracy.

A large sheet of graph paper is desirable. On this, about 8 in. apart, parallel and uniform scales of load and area are laid off in opposite directions. A diagonal is drawn between their (actual) zero points. This diagonal is subdivided in psi. over the desired range by intersections of construction lines connecting various

loads and a convenient area. If an area such as 0.200 sq.in. is selected, the psi. result is five times the load. A final step completes the chart: The various points on the area scale are computed back to diameter and listed on the same scale. This cannot be done initially as the chart construction is based on the area equation and not the diameter. (J. C. GOULD, Metallurgical Dept., Federal-Mogul Corp.)

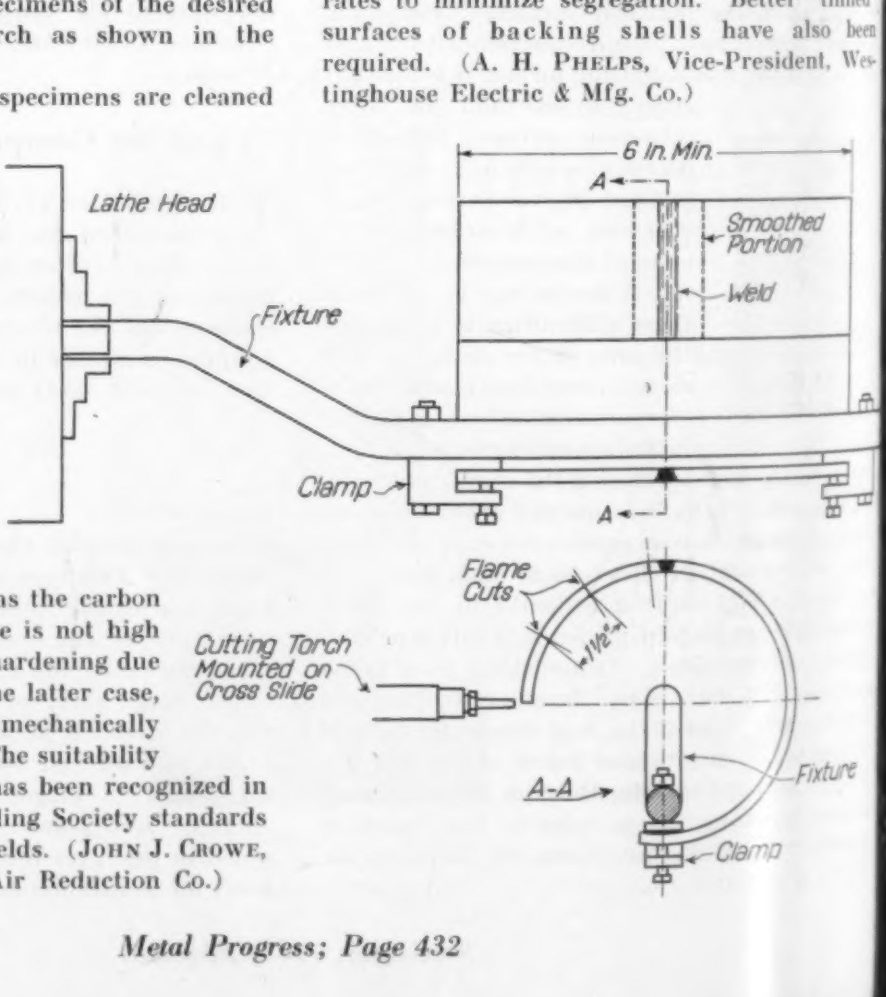
Test Specimens From Welded Pipe

FOR THOSE interested in American Welding Society's and other code requirements for welded piping, a simple and rapid method of preparing the tensile and bend specimens takes advantage of the fact that most carbon and low alloy steels (up to approximately 0.30% carbon) can be oxygen-cut without impairing the ductility of the metal.

Briefly, the ends of the welded pipe sections are cut, if not of suitable length, to a length of from 7 to 10 in., leaving the weld in the exact center. The welded pipe is then mounted in a lathe and machined to remove the reinforcement from both the face and root of the weld. Next, it is placed in a fixture that centers the pipe in a lathe and cut into test specimens of the desired width with a cutting torch as shown in the adjoining sketches.

Cut edges of the test specimens are cleaned of slag and rounded slightly with a file or grinding wheel. Such specimens may be then tested for tensile strength and in cold bending without any further machining.

This method of oxygen machining, without removing the heat-affected zones from the cutting operation along the edge of the weld, gives quite satisfactory testing conditions so long as the carbon or alloy content of the pipe is not high enough to cause excessive hardening due to the cutting flame. In the latter case, the edges would then be mechanically machined before testing. The suitability of specimens of this type has been recognized in the revised American Welding Society standards for mechanical testing of welds. (JOHN J. CROWE, Assistant Vice-President, Air Reduction Co.)



Taking Tin Out of Babbitt

WESTINGHOUSE standards, prior to 1942, called for two babbitts, one with 90% tin (in bearings requiring corrosion resistance, heavy loads, high speeds, elevated temperature, and easy castability) and the other with 8% tin (for many pedestal and bracket bearings). When it became necessary to save tin, many places were found where the engineer "played safe" with the high tin alloy. In one such application alone, the conversion to the 8% tin alloy saved about 40 tons of tin a year.

Two new alloys hardened with arsenic also proved satisfactory. One is the lead-antimony eutectic plus about 1% tin and 3% arsenic. It has good properties at working temperatures and has been used for armature bearings in railway service, subjected to severe pounding. In the other alloy the arsenic is dropped to about 1%; it is suitable for places where hardness is less desirable than ductility. Likewise it can be centrifugally cast.

Associated with this general scrutiny of babbitts, came an improvement in babbitting techniques. Higher casting temperatures gave better fluidity, but required better control of cooling rates to minimize segregation. Better "tinned" surfaces of backing shells have also been required. (A. H. PHELPS, Vice-President, Westinghouse Electric & Mfg. Co.)

A multitude of tests must be made when spot welding aluminum alloy sheet, not only when setting up the job on the machine but at 2-hr. intervals during production. This requires an accurate small machine and handy grips, that can be placed right in the production line.

RAPID AND ACCURATE INSPECTION OF SPOT WELDS

By L. L. ANDERSON

Chief Engineer, Winters & Crampton Corp., Grandville, Mich.

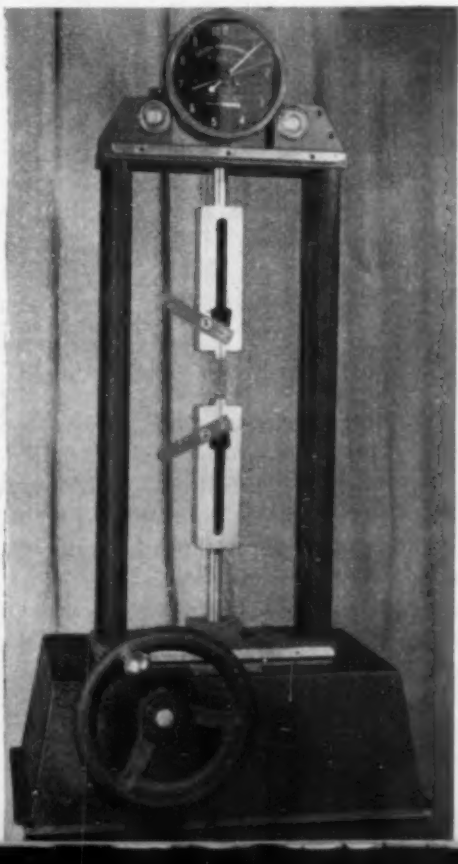
TESTING facilities, quick and handy, are proving absolutely essential to our manufacturing activities (now 100% war production) to provide eyes for the supervisors and inspectors, as well as the workmen themselves — not only as a monitor to the workman, but also to teach him and make it possible for him to see what he is doing. Thus he is able to better the product many times over, usually without increasing the cost. In fact, the cost is decreased by lowering to a minimum the percentage of scrap.

This monitory service afforded by various testing apparatus has gone a long way in reducing our scrap, teaching our employees very rapidly, and making it possible to take inexperienced help and, by showing them where they are erring, advance them very rapidly in the production of high-quality work. It has been through testing and metallographic examination that we have been able to produce very high-quality welded parts of intricate shape and design, with inexperienced employees trained in our plant in a relatively short time.

Being a leading manufacturer in a specialized peacetime line of refrigerator, stove, and range hardware, we had designed and built many testing machines and special pieces of research and development equipment. Our light-load pull tests, mostly of a laboratory nature, had previously been carried out by special equipment made in our own tool room — the total cost of which would doubtless have purchased several light-load testing machines.

Turning to war production, several months of preparation finds us entirely on war products of a half-dozen classifications.

The particular job which made an efficient tensile tester a "must" in our plant was one which required installation of a battery of Taylor-Winfield Hi-Wave spot welders for aluminum sheet. The machines must be qualified at the start of operations, then the spot welds tested and recorded by the Naval Inspector every two hours



Hand Operated Tensile Tester, 7500-Lb. Maximum Capacity, Rigged for Rapid Tests of Spot Welds in Single Shear

during the 24. Quarterly tests must also be submitted to the Naval Aircraft Factory.

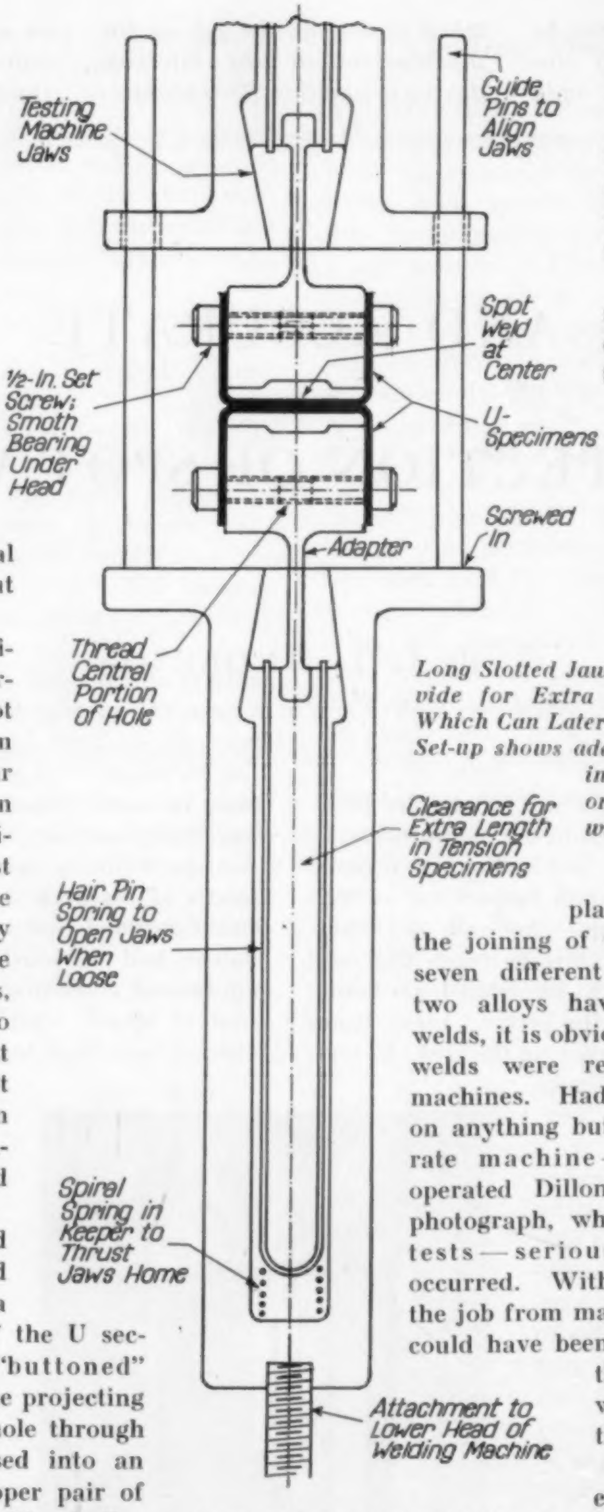
Ordinarily when testing the strength of a fastener, the minimum load is the only limiting requirement. However, in qualifying welding machines under Navy specification PW-6 covering "Processes for Spot Welding of Aluminum and Aluminum Alloys", test results must not only be governed by minimum figures for various material thicknesses and alloys, but also by maximum figures.

According to this specification, when two flat, partially overlapping, single spot welded strips of aluminum are pulled apart in a shear load, and this operation repeated on 25 welded specimens, the high and low test figure must not exceed the average in 21 of the 25 by more than $\pm 10\%$. In the remaining four specimens, the tolerance is extended to $\pm 20\%$. Also, the lowest test result of the group must not be less than a minimum established by the specification for the given alloy and thickness.

In the case of spot weld *tension* tests, two U-shaped specimens are joined by a spot through the bottom of the U sections, which have been "buttoned" together in the welding. The projecting legs of the U each have a hole through which set screws are passed into an adapter leading into the upper pair of tester gripping jaws and with similar means engaging the lower jaws. The device is shown in the line drawing. Springs attached as shown are very handy in providing instant grip on the specimens. The 25-specimen test control which governs the shear test also applies to the tension spot testing, except that the minimum load is based on a figure which is at least 25% of the average of the shear specimens tested.

Other Navy specifications describe the preparation of specimens where weld spots join three and four plies of metal.

The purpose of this somewhat detailed description is to stress the importance of precision testing equipment, since every test has a bearing on the successful qualification of the welding machines. Because the particular job for which our plant was tooled required the joining of various combinations of seven different metal thicknesses in two alloys having two and three-ply welds, it is obvious that hundreds of test welds were required to qualify the machines. Had this testing been done on anything but a fast-operating, accurate machine — such as the hand operated Dillon tester shown in the photograph, which handled all of our tests — serious delays might have occurred. With the "heat" turned on the job from many directions, the result could have been unpleasant for us and the ultimate user, who would not have received the asemblies on time.



Long Slotted Jaws for Tensile Machine Provide for Extra Long Tensile Specimens, Which Can Later Be Trimmed and Re-Used. Set-up shows adapter for testing spot weld in tension. Spring controls on jaws give instant grip when mounting a specimen

Our tensile tester is equipped with a 1000-lb. dynamometer dial with finely spaced graduations for more accurate reading of the loads within this range. We have an additional dynamometer of 7500-lb. capacity, quickly interchangeable with the other after disengaging two hand-operated pins. Some of the tests mentioned above required heavier loads.

For checking electrode pressures, a General Electric 4500-lb. gage is used. We constructed a double sling which is retained by the Dillon tester *(Continued on page 462)*

Prior portions of Otto Almen's notable talk before ⊕ Chapters on "Fatigue of Metals as Influenced by Design and Internal Stresses" have described some common service failures and means whereby the situation can be improved (February, page 209, and May, page 737). Last month the proposition was argued that engineers in mass production industries should usually design for a limited life, and that installment and the present show how the sloping part of an endurance curve then becomes more useful than the stress for infinite endurance.

ENDURANCE OF MACHINES UNDER A FEW HEAVY LOADS

By J. O. ALMEN

Research Laboratories Division, General Motors Corp., Detroit

IN the article on page 254 of last month's issue, entitled "The Useful Data to Be Derived From Fatigue Tests", a working hypothesis was established that the *slope* of the fatigue curve of parts made of heat treated steel, as measured on a log-log plot, may be considered a measure of effective stress. That is, if the line is flat, the effective stress is close to the amount computed for ideal shape and surface; if the line is steep, the test pieces contain stress raisers, either due to irregular surface contour or metallurgical irregularities. Fatigue curves for varying degrees of resulting stress concentrations converge toward a point near the tensile strength of the material, and located out at some considerable number of stress cycles.

It will now be shown how this hypothesis has been used.

It should be remembered that the tensile strength in a test in which the load is slowly increased is lower than in a tensile test in which the load is maintained for a very short time, as in a fatigue test, and also that there is a considerable variation in the tensile strength of any material as measured by a number of tensile test specimens. (See "Deformation and Fracture of Mild Steel Under Cyclic Stresses in Relation to Crystalline Structure" by Gough and Wood, Institution of Mechanical Engineers, March-October 1939, page 175.) Therefore, the tensile strength on a fatigue chart would actually plot as a band and not as a line and would lie above the normal tensile value. Likewise, the lines of a fatigue plot would converge to a region above the normal tensile strength and would probably not meet at a point. However, the inclusion of these variables would considerably complicate the above hypothesis and since they occur in a region of the fatigue plot that has little or no practical value, they may, for the present, be ignored.

The application of this hypothesis to the fatigue strength of machine parts has some important implications. A large variety of machine elements are constantly being tested for relative durability in the laboratories of industries engaged in the manufacture of light weight, high output machines. In most cases these fatigue tests are intended to compare one design, material, or process with another design, material, or process.

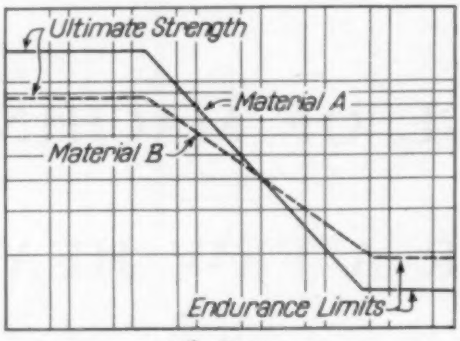
Destructive Tests Necessary

It is axiomatic that nothing can be learned in regard to limiting loads except through tests to destruction and, therefore, the fatigue tests for practically all parts are run to failure and the comparison is made on the number of stress cycles at constant load that each part will withstand. As stated above, this procedure is followed

regardless of whether, in practice, the part in question is stressed below the fatigue limit or whether it is a part requiring relatively short life at maximum stress.

This method of evaluating test results is subject to serious error for several reasons. If it is true that fatigue curves radiate from a point in the high stress region, it is obvious that comparisons of specimens cannot be made on a percentage basis only, since the percentage difference will vary all the way from zero to infinity depending upon the load that is applied during the test.

Fig. 11 — Average Fatigue Curves of Two Materials of Similar Strength May Cross if One Has a Higher Ratio (Endurance Limit to Ultimate Strength)



Furthermore, since the scatter band existing for each machine part tested should also radiate from the same point, as was shown in Fig. 4 of last month's article, the width of the band in terms of life may be several hundred per cent, and unless a considerable number of tests is run for each part there is no assurance that whatever life difference is found is real or just the chance location of these particular test points within the scatter band. It is easily possible that a better design, material, or process will apparently rate lower than the poorer design, material, or process if an insufficient number of tests is made.

Fatigue Curves May Cross

It is possible that the average fatigue curves for two materials having different tensile strengths and yield points will cross at some point in the finite life region due to differences in sensitivity to stress raisers. In such cases, life comparisons may be positive for one material at one test load and negative for the same material at another test load, if the two are put into competition. The diagram on this page, Fig. 11, illustrates such a situation.

It is evident, therefore, that true comparisons can only be obtained through fatigue tests on a sufficient number of parts at varying loads to outline the slopes of the scatter band limits. While this may appear to be an impractical requirement, it is not so difficult as it seems. It is only necessary that the results of the present routine tests be accumulated on a fatigue diagram, and in a relatively short time fatigue curves and their scatter bands will be available for a large variety of machine parts.

Only occasionally are fatigue tests on machine parts run at various loads. In the very few cases where data from a reasonable number of such tests run at sufficiently large load differences are available on commercially identical parts, a reasonable number being 100 or 200, we find that the scatter of the test points when plotted on logarithmic coordinates falls within a well-defined pattern. This pattern tends to radiate from a point at high stress and a low number of stress cycles, and to diverge to a broad band at low stress and high number of stress cycles, just as was suggested in Fig. 4 of last month's installment.

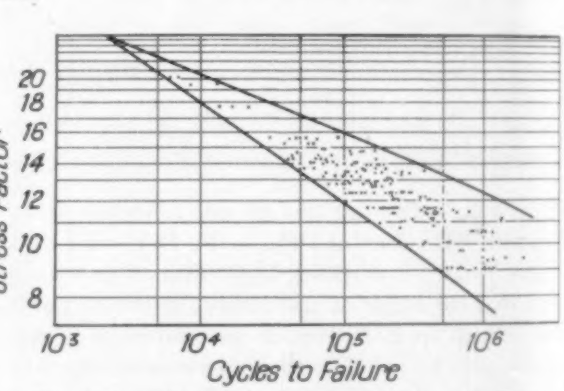


Fig. 12 — 196 Tests to Destruction on Rear Axles for Automobiles (Almen and Boegehold)

Endurance of Rear Axle Gears

This is clearly shown in Fig. 12, which is a fatigue diagram of about 200 complete automobile and truck rear axles of various makes and sizes, taken from a paper by Almen and Boegehold in *Proceedings*, American Society for Testing Materials, Vol. 35, Part 2, 1935, entitled "Rear Axle Gears — Factors Which Influence Their Life". The stress scale shown in this diagram is not actual stress but is believed to be proportional to actual stress. The axles were tested at loads to produce failure of one or more pinion teeth through the range of from 7000 cycles to 1,000,000 cycles. The scatter of the test points is due to variations always present in commercially similar parts, such as in residual stresses, fillet radii, cutter scratches, bearing, shaft and housing deflections, and warpage in heat treatment.

The slope of the average durability line,

calculated as the horizontal distance divided by the vertical distance measured on logarithmic coordinates is approximately seven, while the slopes of the upper and lower limits of the scatter band are respectively nine and five. The intersection point at the left of the diagram should lie near the ultimate strength of the material (approximately 300,000 psi.) which, if proved, would supply us with a measure of actual stress for the entire diagram.

The diagram is not ideal as a proof of the scatter band or the intersection point, since it includes a variety of axles made from various alloy steels variously heat treated for which the stresses were calculated by an empirical formula. Satisfactory determination of the characteristics of the scatter band would require a large number of fatigue tests on one form and size of specimen, made of one type of material similarly heat treated, and tested to produce failure over a range of stress repetitions from as near a single cycle of stress as possible up to the number required to set a true endurance limit.

Ball and Roller Bearing Tests

According to *The Ball Bearing Journal,* No. 3, 1927 (SKF), data approaching these requirements have been accumulated by the various ball and roller bearing manufacturers, but the published data are not yet extensive enough to define

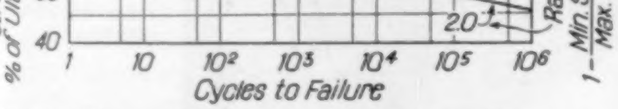


Fig. 13 — Slope of Fatigue Curve for Various Stress Ranges — Top as for a Valve Spring, Middle as for a Gear Tooth, Bottom as for a Crankshaft

the form of the scatter band. Particularly, more data are needed in the very low stress range and in the very high stress range. However, fatigue data on ball and roller bearings need not in all particulars agree with fatigue data on other forms of machine parts, since failure of rolling bearings usually originates below the surface of the material. Many surface influences, which play important parts in fatigue of ordinary machine parts, are, therefore, absent in rolling bearings. This would be expected to influence the permissible stress and possibly the form of the scatter band. The scatter band as reported by Macauley (*The Automobile Engineer,* Vol. 13, July 1923, page 213) and by Styri (*Mechanical Engineering,* Vol. 47, June 1926, page 490), is parallel to the average life curve throughout the life range shown.

Ball and roller bearings are also peculiar in that their S-N curves show no fatigue endurance limit as is usually found in steel fatigue specimens. According to the catalog ratings, the sloped lines continue to more than a billion (10^9) inner race revolutions and since there are several stress cycles per revolution, we do not find a knee in these curves up to more than five billion (5×10^9) stress cycles. See *The Ball Bearing Journal,* No. 3, 1937 (SKF, Toronto).

We seek to determine actual stress only as a step in predicting the adequacy or inadequacy of our designs. Any other means that will enable us to predict the performance of our designs will do as well. Bearing manufacturers do not consider stress in their ratings but rely entirely upon tabulated load capacities. These capacities have been determined by service experience, correlated with laboratory tests on complete bearings. In practice we are not only unable to calculate or to measure stress accurately, but we do not even know the manner of load applications in service on the majority of machine parts.

Laboratory fatigue testing of automobile or other light-weight, high-output machine parts, as well as other laboratory tests such as on fuels, oils, and tire wear, must be correlated with service data on the part in question before the results can be accepted. This requires that, for fatigue strength, tests must be devised that will agree with failures that occur in normal service as to the location of points of fracture and the character of the fractures — whether or not the test procedures agree with preconceived notions of service loading.

Effect of Stress Range

The slope of the finite life portions of the S-N diagram has now been discussed from the standpoint of fatigue tests at constant stress range. Most of the test data presented hereto have been taken from specimens in which the stress was completely reversed. However, many machine parts are otherwise stressed as, for example, properly tightened bolts in which the stress range approaches zero. Valve springs are stressed through a relatively narrow range in one direction only, being preloaded to approximately 25,000 psi. stress which is increased to approximately 90,000 psi. when the valve is fully open. Gear teeth usually are loaded from zero stress to a maximum stress in one direction only. Axle shaft stresses are somewhat more complex, being completely reversed in bending during each revo-

lution due to the weight of the car; they also transmit torque in one direction only.

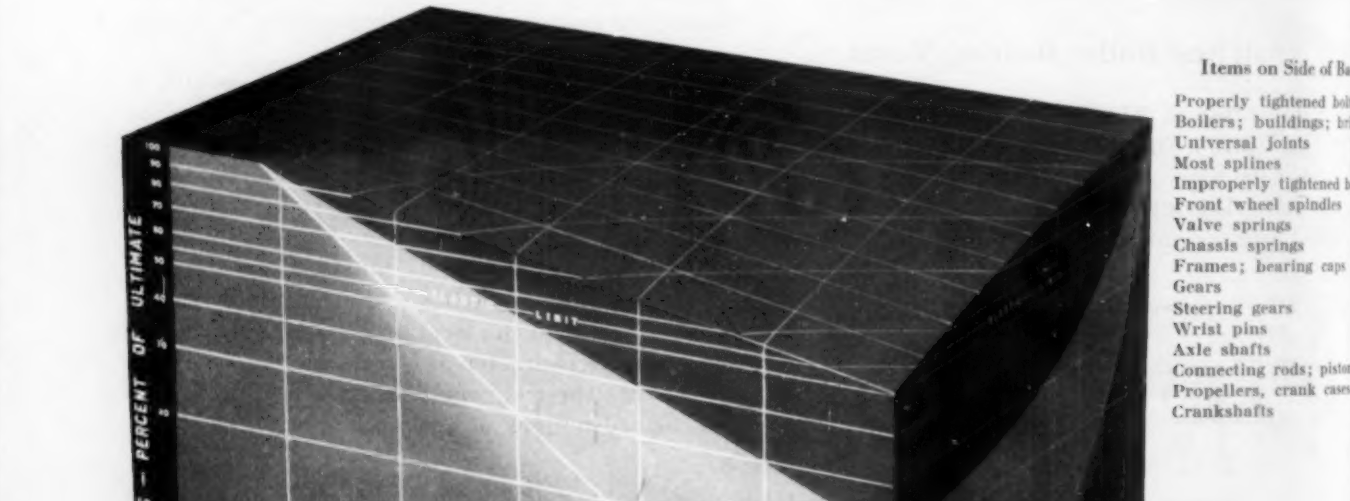
Experiments have been made to determine the effect of varying the stress range, but again interest lay in the stress at the fatigue limit, and little data are available on the change of slope of the curve with stress range. However, since the stress at the fatigue limit increases as the stress range decreases, as has been amply demonstrated, it follows that the slope must decrease (become flatter) as the stress range decreases.

Moore and Kommers in their book on "Fatigue of Metals" present, somewhat apologetically, a modified Goodman diagram from which the fatigue slope for ideal specimens may be constructed for any stress range. Figure 13 (p. 437) shows a replot of this modified Goodman diagram for three stress ranges. The upper line represents a small stress range similar to that of automobile valve springs; the second curve represents a stress range of from zero to maximum as for gears; and the lowest curve represents complete reversal of stress as may occur in a crankshaft. The slopes of these curves are respectively 80, 48 and 17.

We thus see that *slope* of the fatigue curve varies with stress range as well as with stress concentration and, therefore, the hypothesis that the slope of the fatigue curve is a function of the usual conception of stress is no longer tenable. If, however, we state that the slope of the fatigue curve is a function of *effective* stress, the hypothesis will apply for any stress range.

Three-Dimensional Fatigue Diagrams

Figure 14 is a three-dimensional diagram of the modified Goodman diagram by Moore and Kommers. The vertical logarithmic scale of this diagram represents stress, the horizontal logarithmic scale on the forward side represents stress cycles, and the arbitrary horizontal depth scale (front to back) represents stress range.



Items on Side of Base

Properly tightened bolts
Boilers; buildings; bridges
Universal joints
Most splines
Improperly tightened bolts
Front wheel spindles
Valve springs
Chassis springs
Frames; bearing caps
Gears
Steering gears
Wrist pins
Axle shafts
Connecting rods; pistons
Propellers, crank cases
Crankshafts

Fig. 14 — Three-Dimensional Model (Strictly Qualitative) Representing on Its Front Face the Influence of Commercial Variations in Manufacture on the Effective Stress Causing Fatigue Failure at Relatively Short Life, and in Its Depth Representing Effect of Stress Range (Complete Reversal at Front; Slight Fluctuation at Back). At side is a suggested list of actual machine parts whose working stresses come within the indicated range

The forward face is the ordinary S-N diagram for complete reversal of stress; the back face is an S-N diagram for a stress range of zero (static stress); and a section at the middle of the stress-range scale would be an S-N diagram for a stress range of zero stress to maximum stress. The numerical values of the stress-range scale have been arbitrarily selected so that 2 represents complete reversal of stress, 1 represents stress from zero to maximum in tension, and zero represents no change in stress. The equation used in Fig. 13, page 437,

$$R = 1 - \frac{\text{minimum stress}}{\text{maximum stress}}$$

has, therefore, been used to locate points of intermediate stress range.

We find that on the light-colored forward face of this diagram are drawn two straight lines diverging from a point at the upper left. These two lines represent approximately the best slope (upper) and the poorest (lower) that have been obtained from available fatigue tests on machine parts at complete stress reversal. These slopes are such that, at one million stress reversals, the poorest specimens (slope 4) are capable of supporting, by hypothesis, between 7 and 8% of the tensile strength of the material; the best specimens (slope 8) are capable of supporting, by hypothesis, about 23% of the tensile strength of the material; whereas the slope of the Moore and Kommers' diagram (slope 17, the upper edge of the forward face) indicates that, at 1,000,000 reversals, the specimen should support about 50% of the tensile strength of the material.

These conclusions are based upon the further hypothesis, previously stated, that fatigue diagrams are straight lines, on logarithmic coordinates, reaching up and ending at a point on the tensile strength line at some considerable number of stress cycles. Since the data on machine elements indicating the slopes of their fatigue curves are meager, the diagram should be considered as qualitative only.

The stress-range (depth) face shows lines that are even less supported by reliable evidence. They also represent the best and the poorest of fatigue tests on machine parts and are based on one point each at stress range 2, at stress range 1 and converging to a point of stress range zero and ultimate strength. The diagram is presented here in the hope that other experimenters will come forward with data to prove or disprove the hypothesis upon which it is based. Since we have no reliable means for determining stress and since fatigue tests on laboratory specimens cannot be used for evaluating the strength of machine parts, we have no recourse but to continue fatigue tests on machine parts in our industrial laboratories. There is, however, much that we can do to improve our technique in setting up the conditions of tests and in interpreting the test data.

Tests Based on Service Experience

The methods now used for coordinating laboratory tests with service experience are too haphazard to be completely reliable. Service failures must, obviously, be infrequent and when true fatigue failure does occur, it is the result of harder-than-usual service combined with a specimen lying on the lower fringe of the fatigue scatter band. Since failures must be infrequent, it is highly important that failed parts be examined by competent observers in order that the true cause of the trouble may be determined. Clear evidence of fatigue failure does not prove that the failed part was primarily responsible. A bolt may fatigue because it was not properly tightened during assembly; a gear may fatigue due to improper support or to a failed bearing; a crankshaft may fatigue due to inadequate or mal-adjusted vibration dampers; and so on without end. It sometimes happens, therefore, that immediate corrections are made to the wrong part and recognition of the true trouble may be greatly delayed.

Laboratory tests must not only duplicate service failure as to location of fracture, but must, in some cases, produce failure in approximately the same number of stress cycles if accurate life comparisons are to be made. This requires that we distinguish between normal operation stress and the relatively infrequent overloads that caused the failure.

For instance, rear axle automobile gears are, at worst, stressed at low-gear torque one cycle out of every thousand (according to Almen and Boegehold in *Proceedings*, American Society for Testing Materials, Vol. 35, Part 2, 1935, page 99). The lifetime requirement of such gears, therefore, is 100,000 cycles at low-gear torque, equal to about 30 miles of travel. Due to the scatter of test points this is nearly 250,000 cycles measured on the average fatigue curve.

Automobile chassis springs normally operate through a small stress range, but they must be designed to withstand a total of high stress cycles equal to the number of bumps that will be experienced by the hardest driver on the worst road. This is a relatively small number of stress cycles but the problem is aggravated by the fact that such springs are subjected to severe corrosion and to surface damage by stones. Hence experience requires an average lifetime of 100,000 cycles at maximum amplitude.

Clutch springs in town driving are deflected approximately 500,000 times during the lifetime of an automobile, but not always at the maximum amplitude. Therefore, a life of 500,000 cycles at full amplitude is a minimum requirement.

Fatigue data from machine parts can profitably be studied for the purpose of constructing empirical formulas by which load capacity eventually may be accurately calculated.

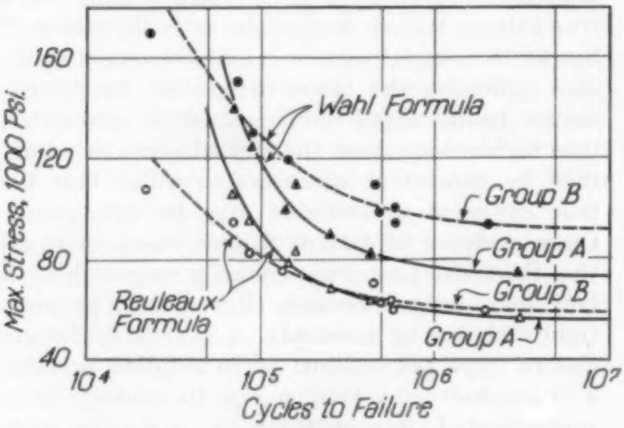


Fig. 15 — Edgerton's Tests on Helical Springs, Plotted on Semi-Log Coordinates. Group A and B are identical, except in diameter of helix. Stresses calculated by two formulas, and Reuleaux's seems to be more reliable as it gives fairly concordant results at long life

Comparison of Stress Formulas

An interesting comparison of the relative accuracy of two formulas for calculating stress in coil springs was made by C. T. Edgerton in "Stress in Helical Compression Springs, Present Status of the Problem" (*Transactions*, American Society of Mechanical Engineers, Vol. 61, 1939, page 643). He plotted semi-log S-N curves for two groups of springs that were identical in every respect except that they differed in the ratio of spring diameter to wire diameter, the spring indexes being respectively 3 and 5. The stresses for both groups of springs were calculated by the method of Rouleaux and by the Wahl method with the results shown in Fig. 15. From this chart Edgerton concluded that the Rouleaux method was superior because the curves for both springs gave approximately the same endurance limit whereas the endurance limit for the two springs calculated by the Wahl method varied by 20%.

When these data are plotted on logarithmic coordinates, as is shown in Fig. 16, and analyzed by the hypothesis previously stated, we cannot escape the opposite conclusion. Note that the curves plotted to the Rouleaux formula intersect at 300,000 or 400,000 stress cycles, an impossible condition by the proposed theory because the materials were identical. The Wahl formula curves intersect in the region of high stress as is required by the theory. The difference in slope of the two Wahl curves is interpreted as differences in stress concentration or in stress range for these two groups of springs. The fact that these data show greater stress concentration or greater stress range for the springs having the greater index requires explanation, but the data at hand are insufficient to permit a more complete analysis.

The numerical value of stress in these springs as shown in the chart is not now important for reasons that have been discussed, nor should it be assumed that the Wahl formula will suffice when adequate data have been studied.

These springs are introduced here to show that the accuracy of practical stress formulas for any machine element can be analyzed no matter how complex the stress pattern if given the necessary fatigue data. This has already been done for a number of machine parts and sufficient fatigue tests have been made on other parts to construct significant stress formulas if they can be assembled for study.

It is realized that the discussions given the

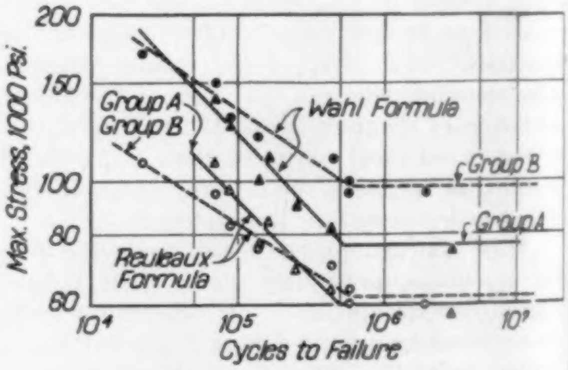


Fig. 16 — Same Tests Plotted on Log-Log Coordinates Indicate That Wahl's Formula Gives Better Agreement With Logic of Circumstances Existing at Heavy Stresses and Short Life

several subjects introduced in this paper are inadequate and incomplete. They are inadequate because of limitations of space and they are incomplete because of meagerness of data. It is hoped, however, that enough has been said to indicate some of the shortcomings of our present procedures and to stimulate action whereby we may improve the efficiency of both men and materials.

In the preparation of this paper the author has been given valuable assistance and suggestions by Howard Grange, Carmin Guerrera, Raymond L. Mattson and John C. Straub, all of the General Motors Research Laboratories Division.

The 1929 failure of heat treated bridge wires forming the main cables of two suspension bridges again attracts attention. The author of the following article, who has had considerable experience with structural engineering problems in modern aircraft, finds similarities to early troubles with looped ends of stay wires in biplanes and rigid airships. An analysis of the initial stresses in the individual wires, where they pass around the anchorage shoes, reveals large residual stresses, all but ignored by former students of this unexplained failure.

RESIDUAL STRESSES IN WIRE LOOPS AT ANCHORAGE SHOES OR GROMMETS

By GIVEN BREWER
Willow Run Bomber Plant, Ford Motor Co., Ypsilanti, Mich.

SALUTARY INTEREST in the subject of internal or residual stresses is being awakened in the minds of engineers everywhere by the troubles encountered in some of our all-welded cargo steamers and tankers. For the present, censorship (naval, industrial and individual) undoubtedly conceals many of the facts. Nevertheless, a good idea of how serious the effects of locked-up stresses can be in large welded structures is contained in the series of articles in *Metal Progress* for June. An elementary study of their causes and avoidance was also printed in this journal last month.

Even without this topical interest it would be well worth while to revert to the subject in connection with the still unexplained (at least not satisfactorily explained) failure of the heat treated bridge wire in the Mount Hope and Ambassador bridges, for residual stresses have strangely been overlooked by students of that metallurgical mistake. Yet they can be clearly shown to have a pronounced effect — at least there is no doubt that residual stresses approaching 120,000 psi. were placed in the wire by the act of forming it about the anchorage loop.

Neither is the problem of looped ends of stiff wire entirely foreign to aircraft construction. "Piano or music wire", the highest quality steel wire, heavily cold drawn to high tensile strength, was used in all the early aircraft for shear and drag bracing within airplane wings and fuselages. Such wires were anchored by looping around steel ferrules; ferrule and loop were then soldered. Such an anchorage would develop 100% efficiency in static tests, but many fatigue failures occurred in service in the loop, without any sign of "ductility". Note that this was not heat treated (quenched and tempered) wire, but cold drawn wire of the same type as the conventional bridge wire. Similar troubles were intensified in the internal bracing of rigid airships of the Zeppelin type containing as many as 30,000 wires under tension, every one with loops at each end. How this problem was solved will be mentioned during the discussion below.

Historical Background

Now to revert to the bridge wire failure. For historical background I quote from the series of articles by Ernest E. Thum in *Metal Progress*.*

These two toll bridges were constructed in 1929 by McClintic-Marshall Co., well-known bridge builders, from designs prepared by the bridge owners. Originally the designers contemplated using cold drawn wire for the main

*June 1932, page 45; July 1932, page 27; August 1932, page 30; September 1932, page 43.

cables — standard since the Brooklyn bridge was built in the 70's — but later the "better" heat treated wire was substituted, it meeting all the required acceptance tests. In fact, it had a higher proportional limit and "yield point" (load at 0.75% elongation in 10 in.). Specified and test values after galvanizing were as shown in the adjoining table.

Bridge cables are "spun" from an endless wire. Tension in the wire is adjusted and it is then looped about the anchorage shoe, one at a time. Cold drawn wire can be snugged up by hand or mallet, but the heat treated wire was so stiff that it had to be wound 1½ times around a 9½-in. preforming sheave; on release, a loop was formed that fit the 19½-in. anchorage shoe fairly well; "lay dead" as the saying is.

In the Mount Hope bridge some broken wire loops were noticed at the anchorages about three months after cable spinning was completed while the suspended trusses and floor beams were being erected. Within another two months so many wires had broken that it was apparent that the bridge was unsafe, so it was dismantled and re-erected with cold drawn wire. The Ambassador bridge, also being constructed with heat treated wire, was not so far toward completion, and serious trouble had not been observed; nevertheless it also was reconstructed.

Since these bridges were to be opened on a certain day, or large penalties paid by the erectors, there was little time for study of the broken wire on the site. A quantity of it was sent to the National Bureau of Standards. Two principal publications have been made.

Explanations of the Failure

The first was the series in *Metal Progress,* about three years after the occurrence, made by the Editor after long study of the circumstances. His principal conclusion was that "the troostitic structure of quenched and tempered eutectoid steel is unyielding and brittle under creeping loads slightly above the elastic limit". His diagrams (not quite correct) recognized that the preformed loop contained such high residual stresses that a relatively small superimposed direct stress in tension brought the extreme fibers up to the elastic limit. In his opinion the success of the cold drawn wire is due to the fact that it has a very low load for permanent set, and it is therefore plastic enough to flow and ease-off high stress concentrations. In a later contribution (August 1936, page 67) he explains the concentration of breaks in certain strands by the rapid increase in tensile load due to the elastic contraction of their anchorage bars, progressively unloaded by the failure of the wires in that strand, one by one — a vicious cycle.

The second important publication was by W. H. Swanger and G. F. Wohlgemuth of the National Bureau of Standards, presented to the American Society for Testing Materials in 1936, and abstracted in *Metal Progress* in August of that year. They tested the above theory by placing 135 loops of wire under increasing loads; eight broke under stresses between 120,000 and 195,000 psi., all in the portion in contact with the support, and 34 with low reduction of area. These investigators concluded that "bending stresses acting in conjunction with tensile stresses did tend to cause a higher-than-normal proportion of the brittle type of fracture", but that it could not be a major influence in the trouble. The investigators then presented extensive tests on hairpins of wire, bent around an anchor shoe and pulled taut, and found that they would break if the pull were fluctuated between 600 and 10,000 psi., whenever the experimental set-up was such that this range of stress permitted the bent wire at the shoe to change its curvature by "spring-back". In other words, minor changes in tensile stress induced major changes in flexural stress, beyond the endurance limit of the material, and fatigue failure resulted.

Without doubting the accuracy of the tests and the direct conclusions, it may be pointed out that exactly the same results of approximately the same magnitudes were found for cold drawn bridge wire, so they have no clear and immediate application to the solution of the puzzle, "why does heat treated wire fail, yet cold drawn wire endure?"

Now the point I wish to emphasize is that the bridge erectors, the men at the Bureau of Standards, and seemingly other commentators as well.

Tensile Properties of the Two Varieties of Wire

	Heat Treated Wire		Cold Drawn Wire	
	Minimum Specified	Average	Minimum Specified	Average
Ultimate strength	220,000 psi.	215,000 to 230,000	215,000	220,000
Proportional limit		150,000		110,000
Yield point	190,000	190,000	144,000	175,000
Elongation in 10 in.	4%	8%	4%	6%
Reduction of area	30%	35 to 40%		28%
Modulus of elasticity		29,400,000		28,000,000

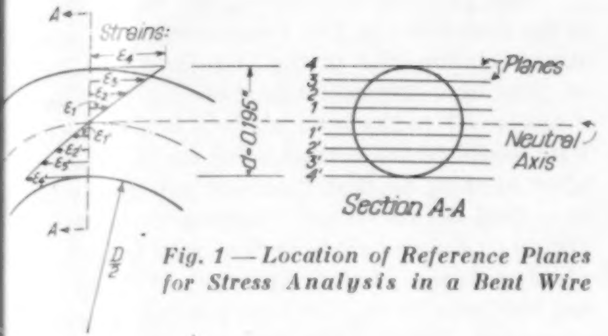


Fig. 1 — Location of Reference Planes for Stress Analysis in a Bent Wire

have neglected the fact that a straight wire looped around an anchorage shoe, ferrule or grommet and pulled up taut is under heavy bending stresses, and further that "preforming" until it "lies dead" at the required radius does not eliminate these internal stresses but merely rearranges them. Swanger and Wohlgemuth write, for instance, "When released from the preforming sheave, the loop would spring open to the approximate curvature of the anchor shoe. The loop was then to be placed around the shoe where it would 'lie dead', and be subjected only to tensile stresses." Note the last clause. Unfortunately, the assumption that the preforming operation if carefully executed would result in the elimination of bending stresses in the wire at the anchor shoe is in error. Actually, upon recovery from the preforming operation residual stresses will exist over the cross-section of the wire. In the Mount Hope bridge a residual tension stress of 120,000 psi. exists at the inner surface of the wire adjacent to the surface of the anchor shoe when it is "lying dead" on the shoe.

The method of determining these residual stresses will now be outlined.

Computation of Stresses

Assumptions: I. Diameter of wire = 0.195 in.

II. Diameter of preforming sheave = 9 in.

III. Planes remain planes during bending and recovery.

IV. The neutral axis does not shift and is considered to be at the geometric axis of the wire.

V. The stress-strain diagram is the same in compression as in tension.

VI. No axial stresses are present during the preforming operation.

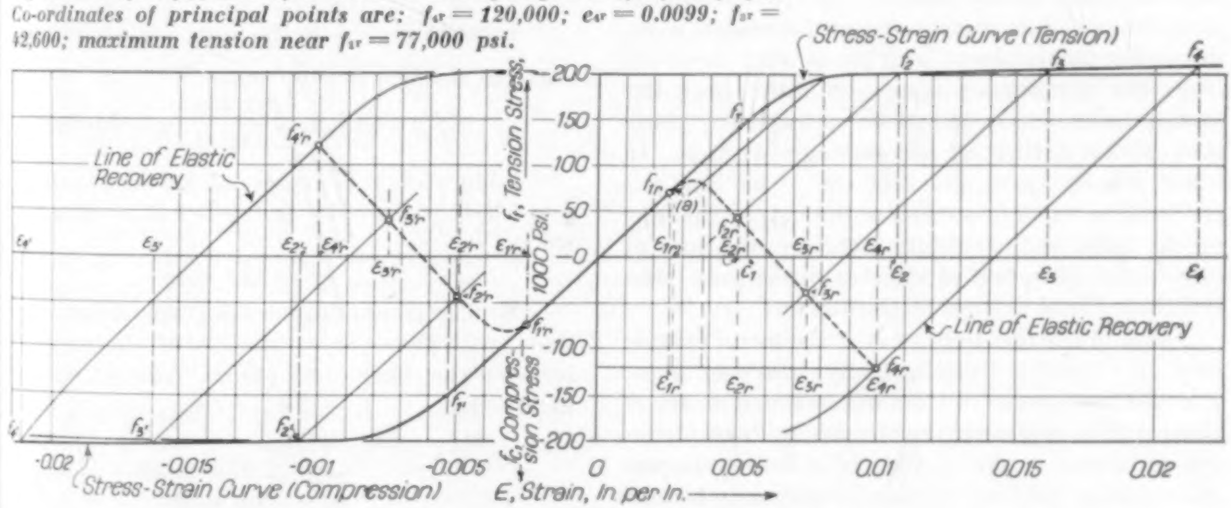
VII. The modulus of elasticity (for recovery) remains constant with increasing strain.

Regard the wire's cross-section to be divided into eight layers by planes parallel to the neutral axis (Fig. 1). When the wire is bent to a given preforming curvature, for example 9 in., the outside fibers are strained to a value given by

$$e_4 = \frac{d}{(D+d)} = \frac{0.195}{9+0.195} = 0.0212$$

where e = strain in inches per inch,
d = wire diameter, 0.195 in.
D = diameter of preforming sheave, 9 in.

Fig. 2 — Stress Distribution in Wire While Wrapped Around Preforming Sheave ($f_{4'}$-0-f_4), and After Release and Springback ($f_{4'r}$-$f_{3'r}$-0-f_{3r}-f_{4r}) Co-ordinates of principal points are: $f_{4r} = 120{,}000$; $e_{4r} = 0.0099$; $f_{3r} = 42{,}600$; maximum tension near $f_{3r} = 77{,}000$ psi.



From assumptions III and IV, the strain at other places (as at planes 3, 2 or 1) can be found by geometry, as shown in Fig. 1. Knowing this strain, the corresponding stress f can be found on the stress-strain curves of tension and compression, and this is done at f_4, f_3.... in Fig. 2. It is obvious that practically all of the wire outside of planes 1 and 1′ has been strained plastically by this operation, either in tension or compression.

Upon release of the forming load the wire will spring open to a larger radius, the stress-strain relationships on each plane of the cross-section recovering on lines parallel to the modulus

line. For example, an extensometer registering movements at the outer fiber will draw the line f_4 to f_{4r}; similarly the opposite inside element $f_{4'}$ recovers to $f_{4'r}$. The exact location of f_{4r} on the line of recovery is determined by the intersection of the inclined line parallel to the elastic action and the vertical through e_{4r}, the strain in plane 4 after springback. e_{4r} can be computed from the fact that the diameter of the loop springs back to 19½ in.:

$$e_{4r} = \frac{0.195}{19.5 + 0.195} = 0.0099$$

f_{4r} determined from this intersection scales 120,000 in compression.

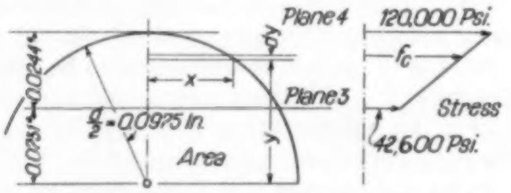


Fig. 3 — Diagram for Figuring Moments

Other points on the dotted line representing the stress-strain relationships of the preformed wire loop are found by similar constructions. Since planes remain planes it can be seen at once that the strain at any plane in the cross-section is proportional to its distance from the neutral axis; therefore, the strain at any plane after recovery from the preforming operation must bear the same relationship to the strain on any other plane that existed during the preforming operation. In other words, $e_{1r} : e_{4r} = e_1 : e_4$, etc. The line $f_{4'r}$, $f_{3'r} \ldots 0$ is the opposite counterpart to the line on the right of the origin; therefore, the sum of tensile and compressive stresses equals zero, thus fulfilling one condition of equilibrium.

Due to the fact that most of the metal outside of planes 1 and 1′ has plastically deformed, plane 1 would have to recover almost as much strain as plane 4 after release if the stresses on both planes are to reduce to zero. This is obviously impossible; strain recovery on plane 1 may only be one-quarter of the strain recovery of plane 4, and the wire will spring open until the stresses across the section of the wire produce a balancing moment. In all cases the strain recovery on the outside fiber will exceed the value necessary to unload the fiber to zero stress, and the stresses in the outside fibers will undergo a change in sign. Thus the outside fiber of the bend which was initially in tension at f_4 will recover through zero stress and finally in the equilibrium position have a stress in compression as shown by f_{4r} on Fig. 2.

The same conditions are taking place save for a change in sign on the compressive side; $f_{4'}$ recovers to $f_{4'r}$ (tension).

The problem of locating the exact position of the dotted line in Fig. 2 representing the stress-strain relationships of the preformed wire is one of trial and error. After several trials with diameter of preforming shoe it was found that 9 in. would be the correct value for D. The wire, after bending to that diameter will spring back to a 19½-in. curvature, whereupon the residual stresses over the cross-section sum to zero, and also produce a balancing moment, thus holding the wire in equilibrium position at 19½-in. curvature. Figure 2 was drawn on that basis, and satisfies the second condition of equilibrium, that the summation of moments must equal zero. To calculate the balancing moment on recovery we first compute the moment of the section between planes. Stresses on planes 3 and 4 are scaled from Fig. 2 as 42,600 and 120,000 psi. respectively.

Moment from stress on an elementary surface $x dy$ about O-O axis (Fig. 3) is

$$dM = 2x dy \cdot f_c \cdot y$$

where f_c is the stress, and by construction

$$f_c = 42{,}600 + \frac{77{,}400}{0.0244}(y - 0.0731)$$

From the geometry of the circle

$$x = \sqrt{R^2 - y^2} = \sqrt{0.0975^2 - y^2}$$

Substituting in the formula for dM we have

$$dM = 2\sqrt{0.0975^2 - y^2} \cdot y \cdot \left[42{,}600 + \frac{77{,}400}{0.0244}(y - 0.0731)\right] dy$$

Integrating this expression between the limits $y = 0.0975$ (plane 4) and $y = 0.0731$ (plane 3) we get

$$M_{3\text{-}4} = -12.97 \text{ in-lb.}$$

Similar computations (or graphical construction) will give the moments of the stresses between the other three planes. The net result is as follows:

$$M_{4\text{-}3} + M_{3\text{-}2} + M_{2\text{-}1} + M_{1\text{-}0} = -12.97 - 1.422 + 12.0 + 2.3 = -0.092 \text{ in-lb.}$$

which is close enough to zero for the second condition of equilibrium to hold.

As noted, several trials were necessary before the value of 9 in. for the preforming sheave was found to give approximately the necessary conditions for equilibrium in a 19½-in. diameter loop. As the bridge construction company used a value of 9½ in. and the Bureau of Standards found a value of 8½ in. necessary for the preforming diameter, the theoretical value of 9 in. determined by the method just described shows good correlation with actual practice. It may therefore be concluded that the stresses determined by analysis are also correct.

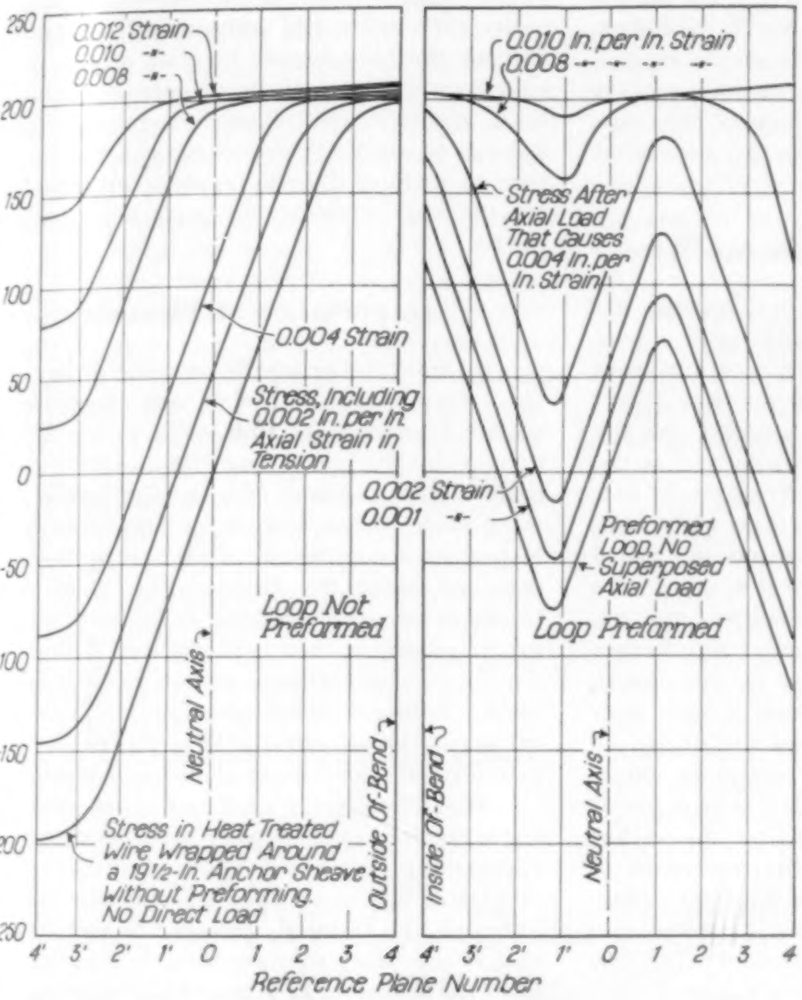


Fig. 4 and 5 — Stress Distribution at Point of Tangency of Loop of (a) Heat Treated Wire Drawn up to Anchor Without Preforming, and (b) Same Preformed to 19½-In. Curvature, Together With Curves Showing Stress Distribution After Definite Tensile Loads (Strains) Have Been Superposed. Note that horizontal scale is contracted and vertical scale expanded, in comparison with Fig. 2

Additional Dead Load Stresses

Note, however, that the preformed loop is *not* free of internal stresses. The residual stresses as obtained by this theoretical development are very high, as may be seen from Fig. 2, being in the neighborhood of 120,000 psi. tensile stress at the inside surface of the wire. These high residual stresses are present before any axial loads are applied to the wire and while it is "lying dead" on the anchor shoe. Clearly these stresses are of sufficient magnitude to vitiate any conclusions in which these stresses were not considered.

Using the same stress-strain diagram as shown in Fig. 2, the stress distribution can be determined over the cross-section of the heat treated wire as it is bent over the anchor shoe *without* preforming. This stress distribution is plotted in Fig. 4, revealing that the outside fiber stress is higher for this condition than when the wire is first preformed. This high stress is recognized by Messrs. Swanger and Wohlgemuth as being responsible for the extremely low value of endurance limit obtained on cold drawn wire when it was subjected to cyclic tensile stresses over a test anchor shoe without preforming.

In the fatigue studies at the Bureau of Standards both kinds of bridge wire were preformed and then looped over a test anchor shoe and subjected to cyclical tensile stresses. The endurance limit as determined from the relationship load÷area was found to be very low — on the order of 25,000 psi. for wiring having an ultimate tensile strength of 223,000 psi.! As can be seen from Fig. 2 a residual tensile stress of approximately 120,000 psi. existed at the inside surface of the wire before any axial load was applied. Residual stresses of this magnitude would most certainly lower the apparent endurance limit, as determined by dividing the external load by the area of the wire (P÷A). The relationship between the *actual* maximum stresses, and the maximum stresses computed by P÷A, are given in the adjoining table. Values in the middle column are taken from Fig. 5.

Apparent Stress (External Load ÷ Area of Wire)	Actual Maximum Stress in Loop: Preformed	Actual Maximum Stress in Loop: Not Preformed
zero	120,000 psi.	200,000 psi.
30,000 psi.	150,000	201,500
60,000	170,000	203,000
110,000	195,000	205,500
155,000	200,000	207,750
200,000	205,000	210,000

Although the presence of residual stresses in accurately preformed wires was not suspected (or at least not thought worthy of mention) by the workers at the Bureau of Standards, Thum

outlined in one of his publications a residual stress distribution closely similar to the one I have analytically determined. V. N. Krivobok has also informed me that by the simple expedient of filing away part of the bent cross-section and observing the change in shape of the supposedly stress-free preformed wire, he discovered that residual stresses did exist in it.

Low Endurance of Cold Drawn Wire

Conventional cold drawn wire, having virtually the same physical strength as the heat treated wire, has been successfully used for years in suspension bridge cables, and yet from Fig. 4 it is seen that very high bending stresses near the ultimate must exist in these wires as well as the heat treated wires, since their stress-strain diagrams are so similar. Yet despite these high bending stresses the cold drawn wire has not failed in years of service while the heat treated wire failed even before its full dead load was applied. Furthermore is the point — of great significance — that the fatigue tests reported by the Bureau of Standards reveal that the cold drawn wire when looped over the anchor shoe and drawn up in the conventional manner had *as low* an endurance limit as did the heat treated wire when it was preformed and then looped over the anchor shoe. Both wires then, under the conditions of their service installations, exhibit the same endurance limit for cyclic tensile loads — yet the cold drawn wire is completely satisfactory while the heat treated wire is as complete a failure.

The presence of the unsuspected high residual bending stresses in the preformed wire can easily explain its low endurance limit, but why did not the even higher bending stresses in the cold drawn wire, with its equally low endurance limit, result in its failure in service? It seems difficult to escape the conclusion that the fatigue tests as outlined did not supply a full explanation for the wide disparity in performance between the two wires.

Importance of Plasticity

In general, the tensile physical properties of the two different materials are closely similar with one exception, that of ductility or plasticity — by that meaning "the ability to flow under stress without fracture". Several tests were made at the Bureau of Standards, by the inspectors accepting the wire, and by the bridge company after the failure, in which tensile fractures occurred *without appreciable or measurable reduction in area* in the heat treated wire. As the two materials — one successful and the other a failure — are almost identical in all physical properties except ductility, the finger of suspicion points unerringly at deficient ductility.

Ductility plays a vital part in relieving forming stresses which are very often ignored by the engineering profession. Figure 2 plots the effect of plastic flow upon the stress distribution, and although the residual stresses are very high, all that is necessary to erase them is that the metal have the ability to flow plastically between 1 and

Photo by Rittase

1½%. The wire then is just as stress-free as if recrystallization had taken place.

The ability of metals to deform plastically and relieve forming stresses is so commonplace that this remarkable phenomenon for the most part passes unnoticed and the average stress analyst never realizes that he owes the close correlation between his elastic analysis and his static test to plastic deformation.

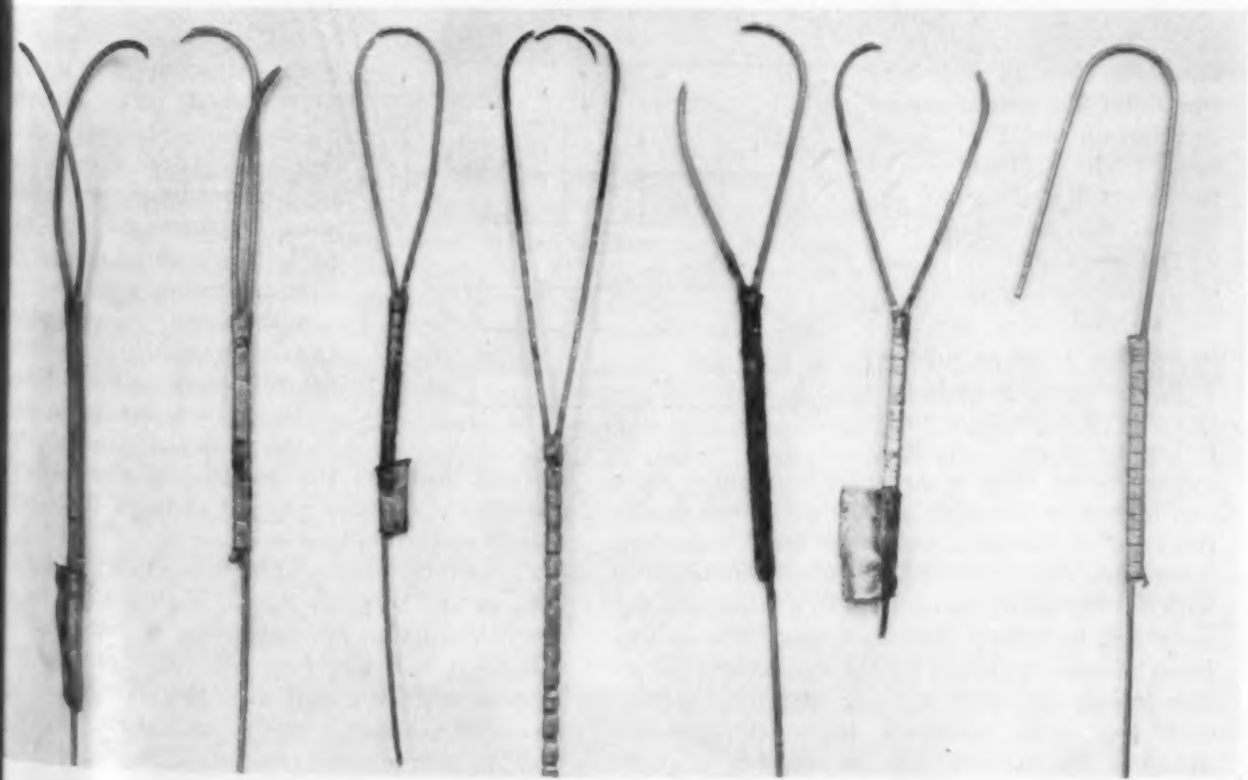
In the Mount Hope and Ambassador bridge failures it would seem that the combined effect of microstructure and surface imperfections reduced the effective ductility of the heat treated wire so that it fell an early victim to the high residual bending stresses which unfortunately existed at the surface — right in the region of deep surface discontinuities. The superior ductility of the cold drawn wire enabled it at least partially to equalize its bending stresses and reduce the notch effect of such surface discontinuities as existed. Furthermore, the surface imperfections in the cold drawn wire are notably less severe than in the heat treated material.

Failure of Music Wire Braces in Aircraft

One final matter may be mentioned, as it conforms nicely with the analysis just given, and yet shows that troubles may arise with cold drawn wire even though bridges seem to be immune. I refer to the failure of cold drawn wire at looped ends when used as aircraft bracing. Karl Arnstein and E. L. Shaw of Goodyear-Zeppelin Corp. have mentioned this matter in an article on "Fatigue Problems in the Aircraft Industry" in *Metals & Alloys* for July 1939. Characteristic fatigue failures are shown in Fig. 6. From the springback it is obvious that unbalanced stresses existed in the loops before fracture. In the third from the right the fracture started from the inside where the wire was held tightly against the grommet, exactly where the maximum residual tensile stress exists, according to the theoretical analysis.

Whenever such failures were scrutinized it was found, according to Paul D. Ffield, then Goodyear's testing engineer, that the wire had carried rapid cyclic stresses or was in a region where resonance had been set up. The complete cure was through devising an air hammer that would peen the wire down against the grommet after it was installed. This operation only took a few seconds, but evidently the wire was plastically deformed enough during that time so that the residual stresses in the loop were ironed out and reduced to a very low figure.

Fig. 6 — Characteristic Fatigue Failures in Bracing Wires of Rigid Airships. Wire is cold drawn piano wire, looped without preforming



FRACTURES IN WELDED SHIPS

By JOHN TUTIN

Reprinted from *The Engineer*, July 9, 1943, page 28

A LOCKED-UP stress may be controlled, like friction, in such a way as to be the servant of the engineer. Uncontrolled, it is likely to be his enemy. For example, locked-up stresses are employed, under control, in many familiar devices, such as a nut and bolt, a rivet, a loaded spring, a shrink fit. Out of control, locked-up stresses may cause the total failure of steel castings, bridges, ships, aircraft, and other structures, large or small. The recent failure of the steamship Schenectady is by no means an isolated case.

A locked-up stress is a stress which exists in a structure not acted upon by any external forces. It follows that in a loaded structure the locked-up stress at any point will be that proportion of the total stress which does not vary with the load.

At any section through an unloaded structure containing locked-up stresses the following conditions of equilibrium must be satisfied: 1. The algebraic sum of the forces acting on any one side of the section is zero. 2. The moment of resistance of the section is zero.

Further rules can now be written down as follows: 3. It is impossible to have a structure containing a single locked-up stress. 4. It is impossible to have a structure containing only two locked-up stresses. 5. The minimum conditions for equilibrium are either three locked-up stresses or two locked-up stresses in association with one locked-up moment. 6. In a pin-connected structure, locked-up stresses cannot exist in any given member unless a line drawn in any direction intersecting that member also intersects at least two other members, in which case the nature of the stresses taken in sequence can only be of alternating signs: (+ — +) or (— + —). 7. In a bracketed or "rigid" structure, locked-up stresses cannot exist in any given member unless a straight line drawn in any direction through that member intersects at least one other member, in which case the stresses must be of opposite sign, with a moment or moments intervening (+, M, —).

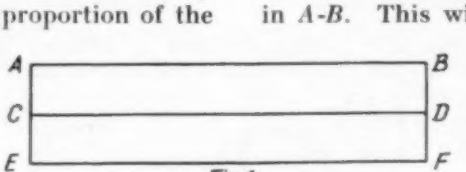


Fig. 1

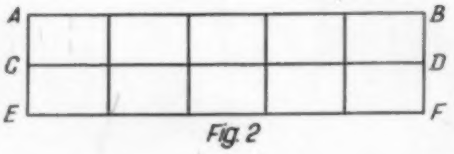


Fig. 2

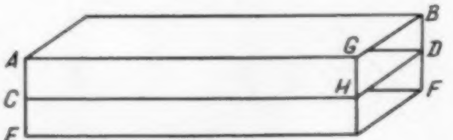
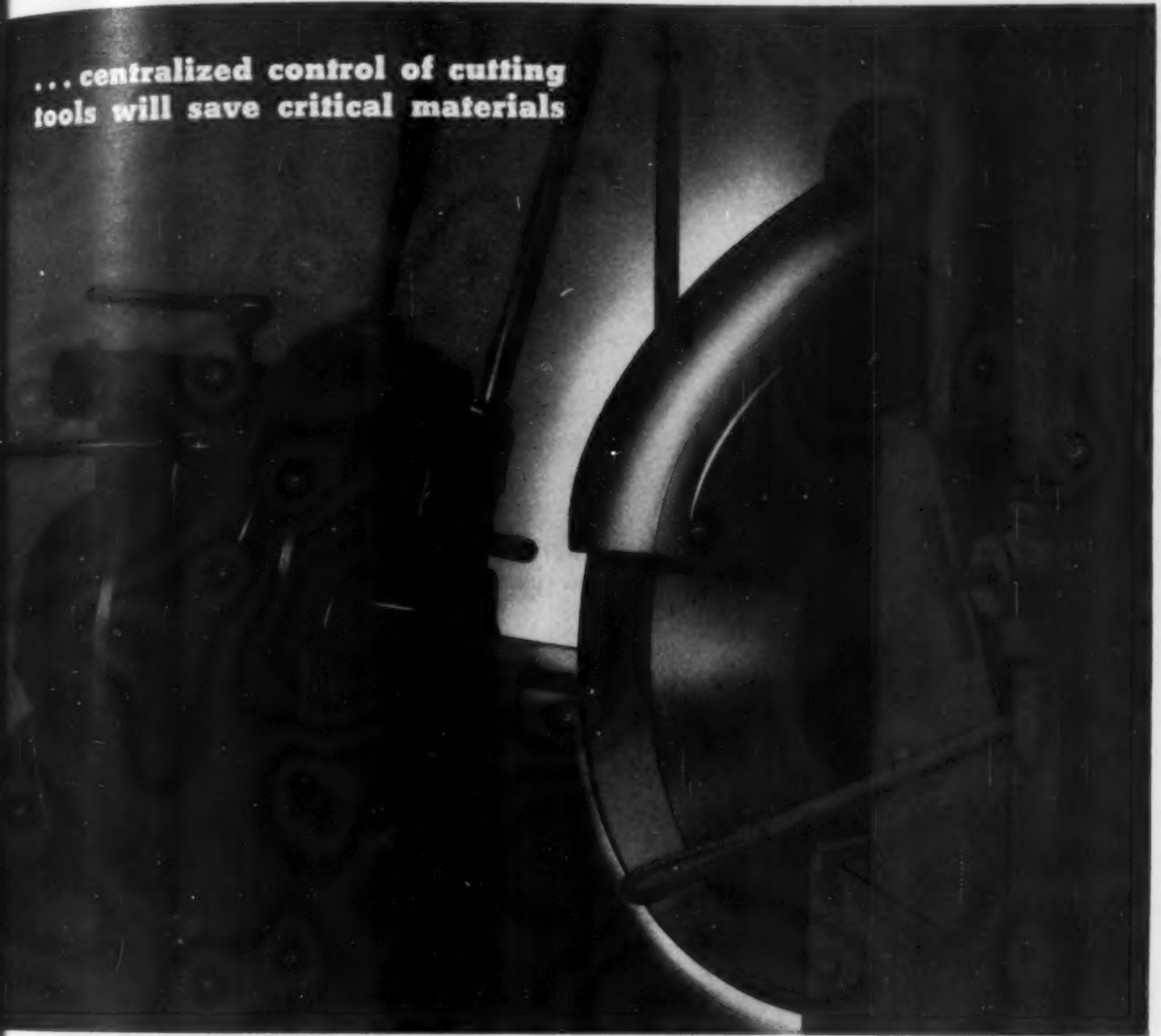


Fig. 3

In relation to the foregoing principles, let us consider the simple example shown in Fig. 1, in which *A-B*, *C-D*, and *E-F* represent horizontal members, connected by vertical members *A-E* and *B-F*. Locked-up stresses may be set up in this structure by introducing, for example, a tension in *A-B*. This will induce a compression in *C-D* and a tension in *E-F*. If the structure is symmetrical and the force in *A-B* is *p*, the force in *E-F* is also *p*, and in *C-D* it is 2*p*. Alternatively, a tension introduced into *C-D* will induce compressions in *A-B* and *E-F*. These stresses also produce bending moments and shearing forces in *A-E* and *B-F*. For a given amount of contraction or expansion in *A-B* the stresses developed in the horizontal members depend solely on the stiffness of the vertical members; that is, the more rigid we make the vertical members the greater the stresses produced by a specified amount of thermal contraction or expansion in *A-B*.

The introduction of additional vertical members, as indicated in Fig. 2, is equivalent, for a specified amount of contraction or expansion in *A-B*, to an increase in the effective rigidity of the vertical members and will therefore result in increased stresses in the horizontal members.

We now proceed from *(Continued on p. 468)*


... centralized control of cutting tools will save critical materials

PERSONALS

JOSEPH J. CHASE was graduated from University of Illinois in June and is now working as research metallurgist for Thompson Products, Inc., Cleveland.

Ensign RICHARD J. SHERLOCK has been graduated from Ft. Schuyler, New York, and is now at Princeton University studying radar.

New appointments by General Alloys Co., Boston: J. B. MCOWEN, field metallurgical engineer for the New York City, Long Island, northern New Jersey, and eastern New York State territory; E. E. WHITESIDE, representative in the northern Ohio and northwestern Pennsylvania area, including West Virginia; PAUL A. FORD, representative in Michigan; A. H. VALENTINE, the southern Ohio area; and R. W. LUZIUS, in California and the Pacific Coast area.

F. C. HUTCHISON, formerly vice-president of the Fairfax Engineering Co., Kansas City, Kans., is now general manager of the Vulcan Engineering Co., Merriam, Kans.

H. C. LARSON has returned to his former position as metallurgical engineer with the Bethlehem Steel Co., Bethlehem, Pa., after 11 months as technical consultant to the Cartridge Case Industry Committee, Office of the Chief of Ordnance, Cincinnati, Ohio.

E. W. RAINEY, formerly metallurgist with Republic Steel Corp. and the Robert W. Hunt Co., Chicago, is now associated with Columbia Steel Co., Pittsburg, Calif. as staff assistant to the wire mill superintendent.

R. J. HAFSTEN has left his position as research metallurgist, Armour Research Foundation, to accept a commission as ensign in the U.S.N.R. as aviation volunteer specialist, and is now stationed at the Post Graduate School of the U.S. Naval Academy at Annapolis.

R. V. BOBB, formerly assistant superintendent, tube division, Aluminum Co. of America, New Kensington, Pa., has been made superintendent of the tube division at the Cressona, Pa. Works.

JOHN R. QUINZIO, formerly designer with the Columbus McKinnon Chain Corp., is now employed by the Sterling Engine Co. of Buffalo, N. Y., in the same capacity.

LILLIAN H. HAMMOND, formerly metallographist at Frankford Arsenal, Philadelphia, is now associated with the Hardy Metallurgical Co. of New York City.

SUNE HERMANSON, formerly chief engineer and metallurgist, Wacho Mfg. Co., Milwaukee, is now in charge of the metallurgical department for Universal Unit Machinery Co., Milwaukee.

ALBERT KATZ, formerly development engineer for Bundy Tubing Co., Detroit, is now in charge of development and research for Ap Metal Tube Co., Elizabeth, N. J.

WILFRED CROSS, formerly with the Wright Aeronautical Corp., Lockland, Ohio, as magnaflux technical supervisor, is now on active duty as an ensign, U.S.N.R.

PERSONALS

W. H. SPARROW, formerly of the Special Ordnance Plant of York Safe and Lock Co., York, Pa., is now metallurgist with the Sperry Gyroscope Co., Brooklyn, N. Y.

Transferred by Rustless Iron and Steel Corp.: F. J. WALTON, from Chicago to Los Angeles, as west coast representative.

A. ALLAN BATES, manager of the chemical and metallurgical department of Westinghouse Electric & Mfg. Co.; ROBERT F. MEHL, head of the department of metallurgical engineering, Carnegie Institute of Technology; ARTHUR PHILLIPS, professor of metallurgy, Yale University; and GREGORY J. COMSTOCK, director of the powder metallurgy laboratory at Stevens Institute of Technology, will present a series of lectures on fundamental metallurgy over a period of a year in a technical educational project established at the Escola Politecnica of the University of Sao Paulo, Brazil, under the joint sponsorship of the Brazilian Government and the U.S. Office of the Coordinator of Inter-American Affairs.

H. J. HEINE has resigned as metallurgical engineer with the Aluminum Co. of America to enlist in the Corps of Engineers, U.S. Army, and is now stationed at Camp Claiborne, La.

DONALD W. KALLSTROM, formerly tool engineer with Remington Arms Co., has been commissioned as ensign in the U.S. Naval Reserve, attached to Ordnance.

ROBERT C. WOODS, formerly director of research at the Taylor-Winfield Corp., has been appointed director of industrial research of the Picker X-Ray Corp., New York City.

BYRON A. WILSON, Government inspection coordinator, of the Copperweld Steel Co., Warren, Ohio, has been appointed assistant inspector of naval materials, U. S. Navy Dept., Cleveland District.

ANSON BIDWELL ALBREE, formerly with A. F. Holden Co., is now in the Materials Division of the Sikorsky Aircraft Division of United Aircraft in Bridgeport, doing metallurgical work on the helicopters.

LEONARD C. PESKIN is now products engineer, Kellett Autogiro Corp., Upper Darby, Pa.

JOHN F. REGIS REYNOLDS, formerly first helper at Jones & Laughlin Steel Co., Pittsburgh, is now melting foreman at Symington Gould Co., Rochester, N. Y.

HAROLD E. HALL, general manager for the past six years, has been elected president of Metals Disintegrating Co., Inc., Elizabeth, N. J.

Promoted by Electro Refractories & Alloys Corp., Buffalo, N. Y.: EUGENE P. HARTER, from sales manager of the grinding wheel division to general sales manager.

Added to the staff of field metallurgical engineers of Alloy Casting Co., Champaign, Ill.: JAMES L. HAGEN, district manager for the state of Michigan; E. W. BOCK, representative in the states of Wisconsin and Minnesota.

HOW TO SELECT THE RIGHT CUTTING FLUID

1. **For Machining Nickel Steel,** and ductile steels generally, if the cutting operation produces a curling chip that bears heavily on the face of the cutting tool, use a cutting fluid high in anti-weld and anti-friction properties. Such properties are generally found in sulpho-chlorinated oils containing some saponifiable material. If visibility and ease of inspection are also of importance the oil should be of the transparent type. Chillo oils No. 140 or No. 143 will be found particularly adapted for service of this kind.

2. **For Similar Operations** but where transparency is not a factor and where the work warrants the use of a lower priced product of the sulpho-chlorinated type, without saponifiable material, we recommend Cities Service Grade A Cutting Oil. This oil has many satisfied users.

3. **For Less Severe Operations** these base oils can be had in milder concentrations to meet varying requirements—of tool life, finish, cost, etc.

4. **If Maximum Protection Against Staining** is a factor, or if a high degree of transparency is desired, in moderately severe operations, a mineral-lard oil in varying proportions, like Chillo Oils 1 to 5, will be found particularly applicable for the purpose.

5. **Where Cooling Is Of Paramount Importance**—as in grinding operations—to assure accuracy and prevent distortion—oil-water emulsions frequently are desired. This type of cutting fluid is also often selected for operations where cost is a deciding factor. We suggest Cities Service Soluble Oil for these requirements.

Call your nearest Cities Service Office today—ask to have a Lubrication Engineer prove the value of these products on your own equipment. There is no cost or obligation.

FOR COMPLETE CUTTING OIL MANUAL, WRITE TO CITIES SERVICE OIL COMPANY, SIXTY WALL TOWER, ROOM 1694, NEW YORK 5, NEW YORK. FREE TO THE PERSONNEL OF USERS OF CUTTING OILS.

CITIES SERVICE OILS · ONCE-ALWAYS

CITIES SERVICE OIL COMPANY
NEW YORK · CHICAGO

IN THE SOUTH
ARKANSAS FUEL OIL COMPANY
SHREVEPORT, LA.

★ ★ OIL IS AMMUNITION—USE IT WISELY! ★ ★

SOLDER

(Continued from page 421)

are practically identical with those after nine months. Average results follow:

Food	Lead Absorbed
Corned beef hamburger	0.09 ppm.
Green beans	0.03
Orange juice	0.08
Evaporated milk	0.34

The Continental Can Co. made similar experiments for eight months at room temperature. Results closely checked the above. Grapefruit juice was also packed in actual No. 2 cans, soldered with either *(a)* 70% lead, 30% tin, *(b)* 95% lead, 2½% silver, 2½% tin, *(c)* pure lead. After four months' storage at room temperature the average for all three was the same, namely 0.07 part per million. Similar tests on tomato juice gave an average of 0.14 ppm. for each of the three solders.

The Pet Milk Co. found 0.16 ppm. after two months' storage of evaporated milk put up in cans soldered with 97½% lead, 2½% silv solder. Continental Can Co. foun that evaporated milk stored fo months at ordinary summer indo storage temperature in contact wi solder disks analyzed less lead th the original milk from the co This was determined to be due the formation of some protein co pound of lead that precipitat tightly upon the can walls and not readily removed save by stro scrubbing. Fairhall in 1937 fou a variation of from none to 0. ppm. lead in canned evaporat milk purchased on the open mark and he packed this milk in ca one-third full of lead-tin pell After 8 months the lead cont varied from 0.06 to 0.30 ppm. Th variability seems explained by t recent work of Continental Can.

It becomes obvious that in no of these representative foods do the use of lead-silver solder pr duce a lead pick-up which, plus t original lead content of the fo itself, comes anywhere near t 2 ppm. taken as permissible.

The remaining question is th of solder spatter — that is, wheth digestive juices would attack acc dentally ingested tiny solder pelle with toxic results. Prof. Cowgil report wipes out any fear on th score:

He fed rats for more than fo months on a diet containing 3 ppm. of lead as solder pellets 97½% lead, 2½% silver, or of 95 lead, 2½% silver, 2½% tin. Th showed no signs of lead intoxic tion and only very slight lead st age. Companion rats fed 300 pp of lead as lead acetate showed le poisoning and had high lead st age. Dr. Cowgill considers th "the pellets under investigation c be regarded as not presenting serious lead hazard when found i such products as, for exampl canned baby foods."

The accumulated evidence lea to the conclusion that the lea silver substitute solder for foo cans does not involve a healt hazard, but is safe.

While economics are no supreme in problems of wartim substitution, it is of interest to no that, either at present pegged price or at normal prices under ampl supplies of tin and silver, the lead silver solder is no more expensiv in raw material cost than the 60% lead, 40% tin solder previousl used. Some can makers prefer th lead-silver solder on can bodie made from electrolytic plate, fo reasons of side seam strength.

PROPERTIES OF METAL FOILS

(Continued from page 424)

are subjected to almost equal stresses, and any tendency to tear the foil is eliminated. Force-deformation curves are obtained by focusing a spot of light reflected from the galvanometer mirror on a screen.

The tensile behavior of the foils examined (force-deformation diagrams) shows no marked difference from that of metals in the forms usually tested, except that the elongations found are often much greater for foils than for the metal in bulk.

Bend Tests — Two types of bend test were adopted — the static bend method, which measures the force-deformation-time relationships under slow bending conditions, and the dynamic bend test, which indicates the permanent set resulting from a severe bending force applied for a short time. For this test it is desirable that the specimen be as large as possible and that the radius of curvature remain uniform throughout the test. This can be achieved by the application of force to the apex of an isosceles triangle of which the base is clamped. A jig of this shape was made and specimens of foil were cut to this size.

Results are inconsistent unless the tendency of the specimens to resume their coiled shape is carefully overcome.

Static Bend Test — The application of continuously variable small, known forces is carried out by means of the repulsion between a magnet and a coil through which a direct current flows in the appropriate direction. The force is proportional to the current if the coil is at a fixed distance from the magnet.

The stressing apparatus consists of a small platform balanced on two jewels. It carries the electric coil at one edge by means of which the platform can be tilted. A rod projects vertically upwards from the center of the platform and ends in a small steel ball which makes contact with the pointed end of the specimen. As this vertical rod is tilted by the force imposed by the electrical coil, it presses against the end of the specimen and bends it away from its original plane position, a movement that can be corrected by rotation of the clamp holding the base.

Movement of the vertical rod is observed through a microscope; a movement of 0.02 mm. is readily detectable.

To obtain a force-deformation curve, the zero position is found and a definite current is passed through the coil. The clamp holding the specimen is then rotated

(Continued on page 458)

Your Bond Selling Responsibilities Double!

Starting September 9th, your Government will conduct the greatest drive for dollars from individuals in the history of the world—the 3rd War Loan.

This money, to finance the invasion phase of the war, must come in large part from individuals on payrolls.

Right here's where YOUR bond selling responsibilities DOUBLE!

For this extra money must be raised *in addition* to keeping the already established Pay Roll Allotment Plan steadily climbing. At the same time, every individual on Pay Roll Allotment must be urged to dig deep into his pocket to buy *extra* bonds, in order to play his full part in the 3rd War Loan.

Your now *doubled duties* call for these two steps:

1. If you are in charge of your Pay Roll Plan, check up on it at once—or see that whoever is in charge, does so. See that it is hitting on all cylinders—*and keep it climbing!* Sharply increased Pay Roll percentages are the best warranty of sufficient post war purchasing power to keep the nation's plants (*and yours*) busy.

2. In the 3rd War Loan, every individual on the Pay Roll Plan will be asked to put an *extra two weeks salary* into War Bonds—over and above his regular allotment. Appoint yourself as one of the salesmen—and see that this sales force has every opportunity to do a real selling job. The sale of these *extra* bonds cuts the inflationary gap and builds added post-war purchasing power.

Financing this war is a tremendous task—but 130,000,000 Americans are going to see it through 100%! This is their own best *individual* opportunity to share in winning the war. The more frequently and more intelligently this sales story is told, the better the average citizen can be made to understand the wisdom of turning every available loose dollar into the finest and safest investment in the world—United States War Bonds.

BACK THE ATTACK *With War Bonds!*

This space is a contribution to victory today and sound business tomorrow by

THE AMERICAN SOCIETY for METALS

METAL FOILS

(*Continued from page 456*)

until the pointer returns to the zero position and the amount of rotation is noted. The current is increased and the procedure is repeated. The rotation of the clamp is proportional to the deformation of the specimen, and hence, if this value is plotted against the appropriate current readings, a force-deformation curve is obtained.

Measurements were usually made to about 0.5-mg. accuracy.

Dynamic Bend apparatus had to be capable of introducing a bending deformation to the specimen for a fixed time and then measuring the recovery of the specimen from this deformation.

The specimen is also in the form of an isosceles triangle whose base is in a clamp and whose flattened apex rests against an appropriate cam. Deformation is set up by rotating this spiral cam against the specimen, which bends the foil a known amount and quickly relieves the force from the specimen. Its subsequent behavior is observed by projecting the image of the specimen onto a screen through an optical contour measuring machine.

On rotation of the cam, the specimen is bent, and when the cam leaves the specimen the specimen is allowed to relax, its movement being measured by means of a radial scale drawn on the screen.

To take a reading the clamp holding the base of the specimen is adjusted so that the tip of the specimen coincides with the zero of the radial scale. The cam is then rotated once. As soon as it allows the specimen to spring back a stop-clock is started and the reading of the tip of the specimen on the radial scale is noted after the required time interval.

Results of Tests — The behavior of foils under bending stresses is a peculiar characteristic of foils as such. Three variables, namely, force, deformation and time, are involved. The mutual relationships of these factors constitute the force-deformation-time surface. The surface derived for bending forces can be applied to tensile characteristics, in which the relationships between the usual types of tensile tests can be interpreted.

It is impossible to correlate the dynamic type of test with the static type. This is because the force-deformation-time surface fails to allow for the irreversibility of plastic deformation.

The thickness of the foil has a very marked effect on these bend experiments, as it is reduced to a value in the neighborhood of 0.03 mm. (which seems to be a critical thickness for zinc-tin eutectic foil). It is not known whether the same thickness is critical for other materials.

WELD INSPECTION

(Continued from page 434)

jaws and into which the pressure gage is inserted. In this manner we are able to prove its accuracy.

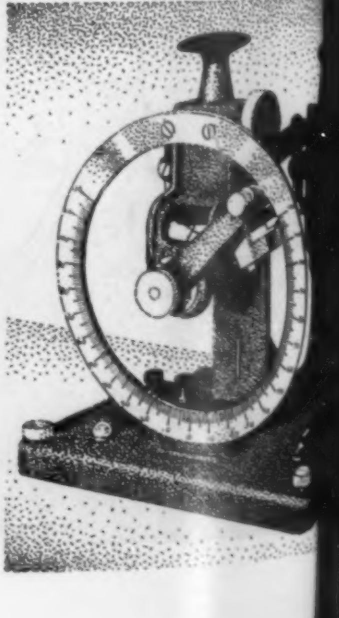
The jaws shown in the drawing on page 434, made to our special requirements, permit the use of long specimens which after testing are cut off at the welded end, permitting re-use. In view of the large number of daily tests, the material saved alone in this way amounts to hundreds of pounds of heat treated aluminum sheet.

Because of the generous space within the frame members of this tester, we have been able to test a variety of other parts. For example, in developing a brazed joint handle consisting of a tubular section joined to a stamping, a decision was quic arrived at relative to the m practical means of constructi

In making projectiles in shell department, we cold fo or compress into an ann groove a driving band of gild metal. This is later shav smooth, and ultimately enga the gun barrel rifling when projectile is fired, thus giving the spin that keeps its point f ward during flight. This driv band, which must conform to requirements of U. S. Army O nance Specification 1366, is straightened, cut to the requir specimen shape, and tested tension. Without correct know edge of quality of the copp alloy tubing from which th sands of bands are cut daily, l from scrap could be great.

With such frequent usages these, our tester becomes prac cally a production machine.

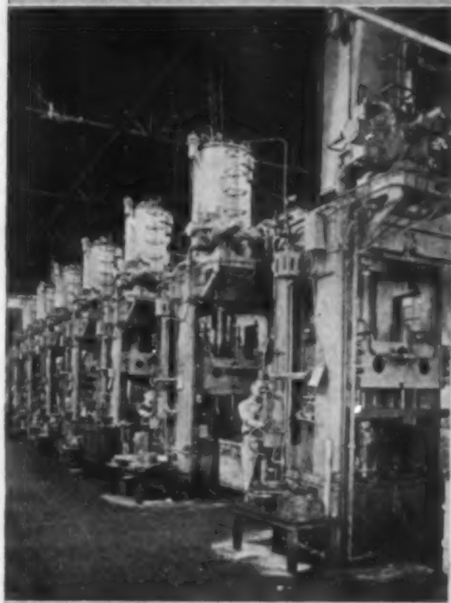
In a plant such as ours, h ing diversified lines of war pr ucts containing fastenings electric arc, gas, atomic hyd gen, and resistance weldi brazing, hand soldering, a high frequency induction sold ing; riveting, clinching, staki and threading, small portab tensile testers are invaluable development work or in l production, and for destruct or non-destructive testing pr to acceptance.



Above is illustrated the progressive stages required to manufacture 57 mm steel cartridge cases.

Above—A close-up view of an H-P-M cartridge case press performing the final draw on a 57 mm steel case.

A battery of new self-contained H-P-M cartridge case drawing presses employed by the Corcoran Brown Lamp Division to draw 57 mm steel cases.



A battery of H-P-M self-contained deep drawing presses used to draw 37 mm steel cases. These presses were installed in 1936 for drawing automobile headlamps. Their conversion to cartridge case production proves their versatility. Below is illustrated the dual punch die set-up for all drawing operations on the 37 mm case.

WELDED SHIPS

(Continued from page 448)

Fig. 2 to Fig. 3 by substituting horizontal surfaces in lieu of *A-B* and *E-F*, and vertical surfaces in lieu of *C-D*, *A-E*, and *B-F*, giving us a hollow closed box. The same general principles still apply. Tension set up in *A-B* will produce an induced compression in *C-D* and an induced tension in *E-F* and the rigidity necessary to transmit and maintain these stresses in equilibrium is largely provided by the resistance to shear in the sides.

It will be seen that Fig. 3 is the equivalent of the box type ship. In the case of a two-deck ship, *A-B* corresponds to the upper deck, *C-D* to the second deck, and *E-F* to the double bottom. The sequence of construction is usually such that the final welding of the upper deck is liable to set up a thermal contraction, thus inducing a compression in the second deck. These stresses may be serious even if no further stresses come on the structure, but when combined with the normal bending stresses in a seaway or even in still water, it is not surprising that failure may ensue.

Several observations may be made in this regard:

1. The locked-up and service stresses in the upper deck in the hogging condition are additive.

2. The locked-up compressive stress in the second deck will prevent that deck from carrying tensile stress in the hogging condition, until sufficient bending has taken place in the hull to bring the plating into tension.

3. The effect of this induced compression in the second deck will be to increase the tensile stress which the upper deck must carry. In fact, until the compression in the second deck has been reduced to zero the vessel must be regarded as a single-deck ship in its resistance to longitudinal bending.

4. The induced compression in the second deck will tend to produce buckling, and if buckling occurs it is likely to coincide in longitudinal position with the incidence of locked-up tension in the deck above. The marked tendency of the ends of a welded ship to lift from the ways during construction indicates the magnitude and nature of the forces at work.

5. Stress transmission between the upper deck and the side shell will augment the load carried by the sheer-strake and stringer connection, the welding of which calls for special consideration in relation to peak loads in the hogging condition.

6. The reaction tension in the double bottom (keel, bilge, and tank top) will normally be considerably less than the tension in the upper deck (equating moments about the second deck). Therefore the double bottom may be expected to function with reasonable efficiency in both the hogging and the sagging condition.

7. The upper deck, in the sagging condition, cannot develop a compression stress until the tension therein has been reduced to zero.

8. The neutral axis in a seaway will be in a state of vertical oscillation relatively to the keel.

9. The hull deflection for moderate conditions of loading will, if locked-up stresses are present, be greater than anticipated, due to the

(Continued on page 470)

WELDED SHIPS

(Continued from page 468)

reduction in effective moment of resistance. On the other hand, the deflection associated with incipient local fracture will be much less than anticipated owing to the reduction in the margin of safety. This, in a sense, is equivalent to a **"reduction in flexibility"**.

10. At the change-over point between hogging and sagging, in association with a sudden movement of the neutral axis, there will be a sudden increase in the time rate of change of hull deflection. This "snap" effect is important in relation to the impact values of the plating and weld metal.

The Schenectady broke in two in still water with a calculated maximum stress of 10,000 psi., indicating the presence of locked-up stresses of considerable magnitude, even after making full allowance for other factors. Less spectacular but equally important fractures have occurred from time to time, on the stocks, in still water, and at sea. Calculations made for the Liberty all-welded ship show that the effect of an induced compression in the second deck may by itself cause an increase in the nominal service stress on the upper deck of the order of 30%, apart from the numerical values of locked-up stresses and stress raisers. Incidentally, an inspection of a major fracture on one of these vessels revealed that the fracture, which started in the upper deck under tension, entered the second deck in way of a pronounced transverse buckle, the crack running significantly up the trough of the buckle.

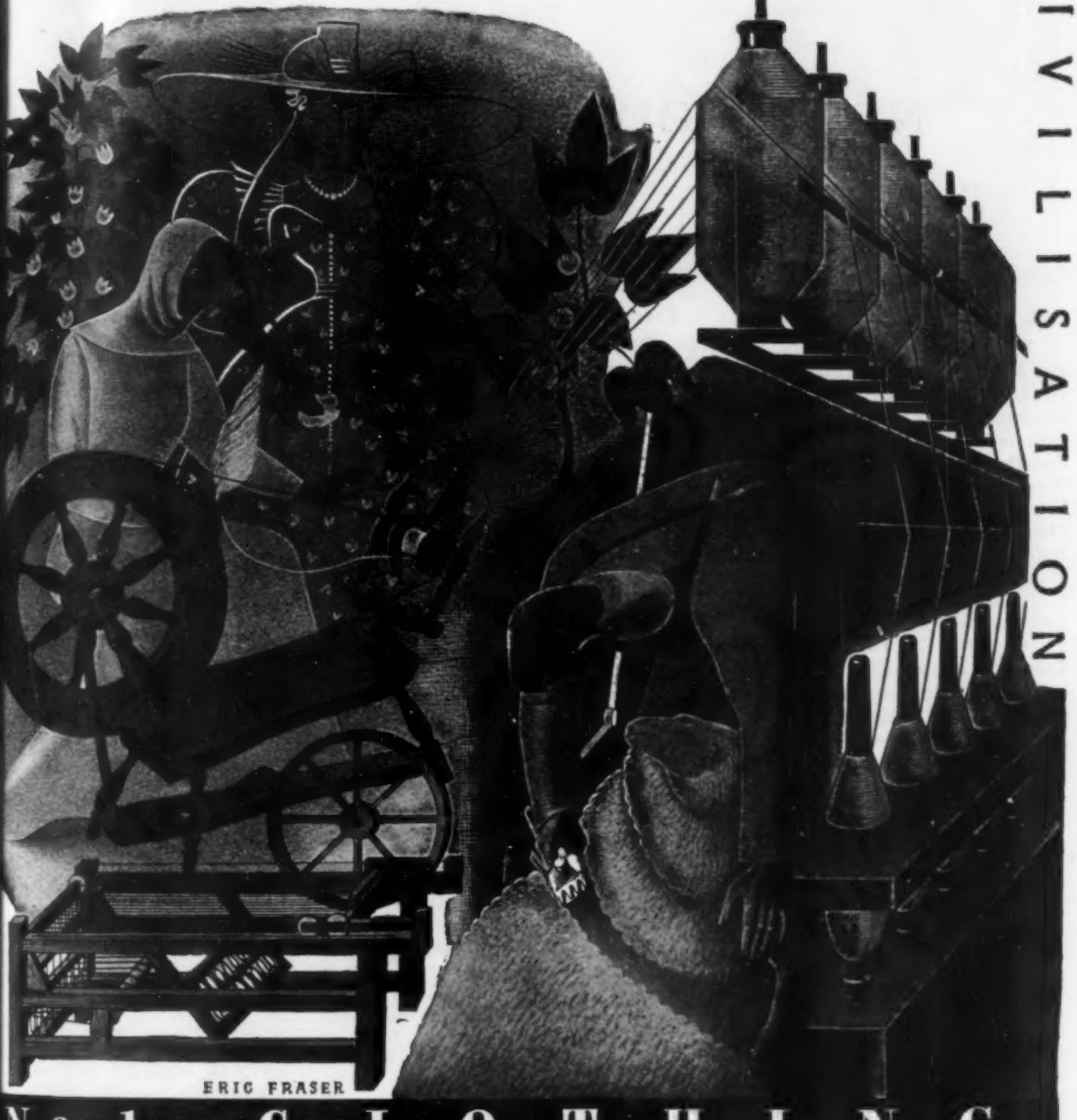
Locked-up stresses are not unknown in riveted ships, and are equally undesirable, but as a rule are better understood and more easily remedied.

In new welded ships the prevention of major locked-up stresses should primarily be the responsibility of the structural designer. Correct design should make it immaterial whether or not a given welding procedure or type of welding machine may tend to cause locked-up stresses. There are ways of insuring safety without impairing the efficiency of the structure against service loads or impeding production. For example, a locked-up stress can be prevented by introducing a transverse line or lines of rivets. If there is any doubt, a complete transverse belt of riveting can be arranged right across the ship at a convenient station. Since in most cases the action stress resides in the upper deck, it might prove a sufficient precaution to confine this band of riveting to the upper half of the structure.

It would obviously be wrong to regard such an arrangement as an expansion joint, for it is essentially a means of stress relieving. The effect of a completely riveted sheerstrake to stringer connection would be very similar and should be adequate if confined to the amidship half-length. Any such riveting should always be completed last.

At least one important Continental shipyard employs the riveted belt amidships on all welded vessels, including warships, this particular shipyard having adopted this construction as a result of practical experience with welded ships over a number of years.

UNDAMENTALS OF CIVILISATION



No. 1 CLOTHING

Textiles and the machines to make them ushered in the industrial revolution. For centuries the wooden spinning wheel, clumsy and laborious, produced homespun for the yeoman and labourer and fine silks and satins for the rich. Modern mechanical engineering was born with the invention of the machines to spin and weave and with the engines required to drive these frames and looms. Tools of steel became necessary to shape and to fashion in quantity these instruments of the great textile industries. Thus grew the art and practice of steel making with its wealth of materials of special quality for making every kind of complex mechanism. Without steel it would not be possible to produce the great variety of woven fabrics now available and essential to the needs of civilised man.

THE UNITED STEEL COMPANIES LTD

HE UNITED STEEL COMPANIES LIMITED

17, WESTBOURNE ROAD, SHEFFIELD 10, ENGLAND.

EL, PEECH & TOZER, SHEFFIELD
MUEL FOX & CO. LTD., SHEFFIELD
NITED STRIP & BAR MILLS, SHEFFIELD

APPLEBY-FRODINGHAM STEEL CO. LTD., SCUNTHORPE
WORKINGTON IRON & STEEL CO., WORKINGTON
THE SHEFFIELD COAL CO. LTD.

THE ROTHERVALE COLLIERIES, TREETON
UNITED COKE & CHEMICALS CO. LTD.
THOS. BUTLIN & CO. WELLINGBOROUGH

U.S.P. 28

NEW PRODUCTS

Distributors for Roto-Finish

The Sturgis Products Co., Sturgis, Mich., manufacturers of Roto-Finish and other mechanical finishing supplies and equipment, announce the following firms as distributors for their products: Wagner Bros., 1249 Holden Ave., Detroit; Frederic B. Stevens, Inc., 510 Third St., Detroit; MacDermin, Inc., Waterbury, Conn.; Munning & Munning, 202 Emmett St., Newark, N. J.; Crown Rheostat & Supply Co., 1910 Maypole Ave., Chicago; Geo. A. Stutz Mfg. Co., 1641 Carroll Ave., Chicago; Lasalco, Inc., 2820 LaSalle Ave., St. Louis; Sommers Bros., 3439 N. Broadway, St. Louis; W. M. Fotheringham, 977 Niagara St., Buffalo; W. D. Forbes Co., 303 Washington Ave., N., Minneapolis; The Reynolds-Robson Supply Co., 4623 Paul St., Frankford, Philadelphia.

3-in-1 Heat Treating Unit

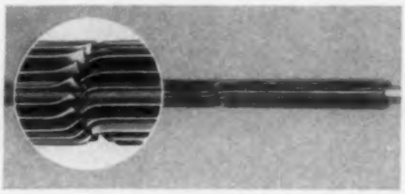
High speed heat treating unit with three pots ranging in temperature from 1000 to 2350° F. is offered by the A. F. Holden Co., New Haven, Conn. Among advantages claimed for this Type 230 unit are: No scale at any temperature; tools hardened with minimum diameter change regardless of temperature; uniformity of hardness and heating on thin or heavy sections. Illustrated below.

Precision Surface Plate

Manufactured by the Herman Stone Co., Dayton, O., for inspection, tool room and production departments. Made of natural granite; will not rust, corrode or warp. Finished to 0.0001 in. over-all.

Cut and Twisted Fintubes

"Cut and twisted" Fintubes have been added to line offered by Brown Fintube Co., Elyria, O. This resistance-welded, integrally-bonded tube provides the heat radiating or absorbing capacity of from 6 to



10 ft. of plain bare tube. When fins are cut and twisted as shown in the view, a much greater turbulence is produced on the liquid passing through the shell. Thermal efficiencies are therefore increased up to 50% in sectional hairpin and other types of heat exchangers.

Circular Division Tester

Introduced by Engis Equipment Co., 310 S. Michigan Avenue, Chicago, it comprises a master circle unit and a microscope unit, suita[ble] for checking spacings in ge[ars,] camshafts and similar parts. In [use] the master circle is attached to [the] part to be checked, centered in [its] mount by means of radial adjust[ing] screws and precise dial indica[tor.] a groove around the periphery [of] the master circle. This groove [is] adjacent to a silver band accura[tely] graduated to degrees and sixths.

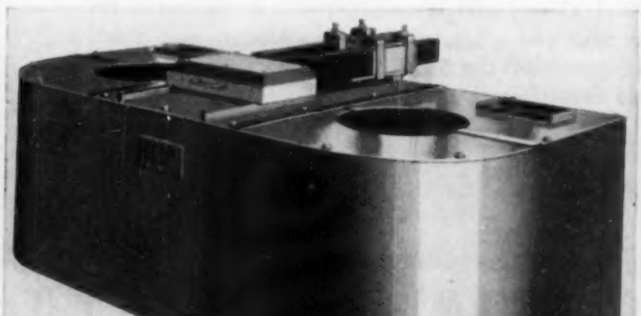
"Fuel Oil and Its Combustion"

A new booklet prepared by [the] research department of North Am[er]ican Mfg. Co., 2910 E. 75th Str[eet,] Cleveland. Crude oil constitu[ents] and classification, crude oil pr[oc]essing, properties of fuel oils, [and] oil combustion are discussed. [Of]fered by North American for $1[...] postpaid.

Laboratory Furnaces

Complete new line of laborat[ory] furnaces, new in appearance [and] construction, has been develop[ed] by the Lindberg Engineering [Co.,] 2444 W. Hubbard St., Chicago[,] Ill. Line includes box furna[ces,] combustion tube, crucible furna[ces] and hot plates, patterned, in m[...]

(Continued on page 480)



NEW PRODUCTS

(Continued from page 478)

respects, after the firm's production furnaces. They incorporate convenient door operating mechanism; low voltage, high temperature heating elements; Lindberg input control for smooth, stepless apportioning of heat; clean, streamlined shape which matches other modern laboratory equipment as well as contributing to a high standard of laboratory cleanliness. **Available in different sizes for operation on 110 or 220 volt, A.C. or D.C.**

X-Ray Film File

Filing cabinet for X-ray film, built largely of wood and obtainable without a priority, is offered by General Electric X-Ray Corp., Chicago 12, Ill. Each of three drawers holds approximately 600 films in negative preservers, and is divided into five compartments so that films are held upright. Overall dimensions are 23¼ in. wide, 28 in. deep, and 55 in. high.

15 KW Tocco Junior

New, highly flexible 15-kw. o[utput], Tocco Junior induction heati[ng] machine is announced by the Oh[io] Crankshaft Co., Cleveland 1, Oh[io]. A small and compact 9600-cyc[le]

high-frequency unit, it is the s[ev]enth model in the compan[y's] "Junior" line. Can be adapted [to] brazing, annealing, heat treati[ng], heating for forging and surf[ace] hardening of small and medi[um] sized parts.

Odors Removed From Paint

Effective with brush or spr[ay] operation, a small quantity [of] Ridsmel, liquid paint deodor[ant], may be mixed with any paint, v[ar]nish or enamel, eliminating [the] usual odors completely. Test qu[an]tities offered by Holley Chemi[cal] Co., 125 E. 25th St., New York.

Searchray

Electronic Searchray, hou[sed] complete in modernistic cabi[net], announced by North Americ[an] Philips Co., Inc., Dobbs Ferry, N. [Y.], is a simple, compact X-ray u[nit] which can be operated safely [by] unskilled personnel for any co[ndi]tion for which X-ray inspection [is] desired. Marketed by the compan[y's] industrial electronics division [at] 419 Fourth Ave., New York.

Glass Lined Tanks

Replacement of worn-out equ[ip]ment is a major problem tod[ay] with many special materials scarce, even for small repair jo[bs]. Metal tanks for plating, dipping a[nd]

(Continued on page 484)

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

METAL WORKING • FABRICATION

Powdered metal presses producing millions of metal parts illustrated in catalog by Kux Machine Co. Bulletin 1.

Forging presses. Ajax Mfg. Co. Bulletin 2.

Horizontal extrusion presses. Hydropress, Inc. Bulletin 3.

36-page pictorial story of the Cecostamp. Chambersburg Engineering Co. Bulletin 4.

Cutting Oils. Cities Service Oil Co. Bulletin 5.

Cutting Oil Handbook. D. A. Stuart Oil Co. Bulletin 6.

Presses for Powder Metallurgy. F. J. Stokes Machine Co. Bulletin 7.

Properties and uses of cutting oils. Gulf Oil Corp. Bulletin 8.

"Dag" colloidal graphite as a high temperature lubricant. Acheson Colloids Corp. Bulletin 248.

Information and data on straightening press. Anderson Bros. Mfg. Co. Bulletin 10.

Forty different ways to cut machining costs. Continental Machines, Inc. Bulletin 11.

Properties, applications and use of hard-facing rods. Coast Metals, Inc. Bulletin 249.

Surface coated abrasive belts. Minnesota Mining & Mfg. Co. Bulletin 12.

Presses for the metal working and process industries. Hydraulic Press Mfg. Co. Bulletin 20.

Handbook on aircraft riveting. Cherry Rivet Company. Bulletin 14.

Savings in oils, tool bits, grinding wheels. Sparkler Mfg. Co. Bulletin 15.

265-page textbook covers techniques used in contour machining, laboratory controls in manufacture of precision saw bands. Doall Service Co. Bulletin 16.

New catalog illustrates standard, non-standard, and special tools, shows prices of tools and blanks. Kennametal, Inc. Bulletin 250.

Mounted wheels, Handee and Hi-Power tools. Chicago Wheel & Mfg. Co. Bulletin 21.

20-page booklet on cutting fluids. Tide Water Associated Oil Co. Bulletin 252.

Many applications for the Norton open structure grinding wheel are shown in leaflet issued by the Norton Co. Bulletin 253.

Air tools in steel mills and foundries are pictured in new booklet by Ingersoll-Rand. Bulletin 255.

Parsons oval bag dust arrestors are described and 12 advantages listed in folder issued by Parsons Engineering Corp. Important advantage is reclamation of valuable dust. Bulletin 228.

Illustrated booklet describes hand stoning of metal cutting tools. Behr-Manning Corp. Bulletin 304.

New Wheel Speed Table will interest those engaged in polishing and buffing. Recommended speeds are shown in red. Divine Brothers Co. Bulletin 310.

Key to efficient automatic finishing is described in new 8-page illustrated bulletin showing Hammond Machinery Builders' rotary table automatics. Bulletin 311.

Big, comprehensive catalog illustrates line of power presses offered by Minster Machine Co. Bulletin 320.

Complete and valuable study of "Machining of Metals", including chip formation, is offered by National Refining Co. Bulletin 335.

FERROUS METALS

Machinery steel selector has been issued by the Elastuf group which includes Horace T. Potts, Brown Wales and Beals, McCarthy & Rogers. Bulletin 256.

Aircraft steels, bearing steels. Rotary Electric Steel Co. Bulletin 24.

Steel Data Sheets. Wheelock, Lovejoy & Co. Bulletin 25.

Molybdenum wrought steels. Molybdenum Corp. of America. Bulletin 26.

Chemical analyses, shapes and sizes of Joslyn stainless steel products are presented in extras and deductions booklet just issued by Joslyn Mfg. and Supply Co. Bulletin 297.

Free Machining Steels. Monarch Steel Co. Bulletin 30.

Tool Steels. Bethlehem Steel Co. Bulletin 31.

Die Steels. Latrobe Electric Steel Co. Bulletin 32.

Enameling iron sheets. Inland Steel Co. Bulletin 33.

Loose-leaf reference book on molybdenum steels. Climax Molybdenum Co. Bulletin 35.

Use Handy Coupon Below for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 486, 490, 492, 494, 496, 498, 500, 502, 504 and 508.

Metal Progress 7301 Euclid Ave., Cleveland 3, Ohio — September, 1943

Send me the literature I have indicated below.

Name .... Title ....

Company .... Address ....

(Students—please write direct to manufacturers.)

Check or circle the numbers referring to literature described on these 11 pages.

1	21	41	61	81	101	121	141	161	181	201	221	241	261	281	301	321
2	22	42	62	82	102	122	142	162	182	202	222	242	262	282	302	322
3	23	43	63	83	103	123	143	163	183	203	223	243	263	283	303	323
4	24	44	64	84	104	124	144	164	184	204	224	244	264	284	304	324
5	25	45	65	85	105	125	145	165	185	205	225	245	265	285	305	325
6	26	46	66	86	106	126	146	166	186	206	226	246	266	286	306	326
7	27	47	67	87	107	127	147	167	187	207	227	247	267	287	307	327
8	28	48	68	88	108	128	148	168	188	208	228	248	268	288	308	328
9	29	49	69	89	109	129	149	169	189	209	229	249	269	289	309	329
10	**30**	**50**	**70**	**90**	**110**	**130**	**150**	**170**	**190**	**210**	**230**	**250**	**270**	**290**	**310**	**330**
11	31	51	71	91	111	131	151	171	191	211	231	251	271	291	311	331
12	32	52	72	92	112	132	152	172	192	212	232	252	272	292	312	332
13	33	53	73	93	113	133	153	173	193	213	233	253	273	293	313	333
14	34	54	74	94	114	134	154	174	194	214	234	254	274	294	314	334
15	35	55	75	95	115	135	155	175	195	215	235	255	275	295	315	335
16	36	56	76	96	116	136	156	176	196	216	236	256	276	296	316	336
17	37	57	77	97	117	137	157	177	197	217	237	257	277	297	317	337
18	38	58	78	98	118	138	158	178	198	218	238	258	278	298	318	338
19	39	59	79	99	119	139	159	179	199	219	239	259	279	299	319	339
20	**40**	**60**	**80**	**100**	**120**	**140**	**160**	**180**	**200**	**220**	**240**	**260**	**280**	**300**	**320**	**340**

NEW PRODUCTS

(Continued from page 480)

coating processes are therefore steadily being replaced with glass tanks, according to officials of the Pittsburgh Plate Glass Co., Pittsburgh, and existing tanks are being relined with glass. "Carrara" structural glass linings are suitable for pickling processes, and have been installed at several of the nation's largest manufacturing plants. At one factory, large reflectors for war use are being dipped in glass-lined tanks 8 ft. long and 8 ft. deep, and a leading manufacturer of wire products has just installed glass-lined dip tanks. Carrara structural glass is impervious to acids, alkalis, chemicals, and liquids of almost any kind. It is non-absorptive and non-porous, and will not rot. It is tempered to resist thermal shock and is obtainable in opaque or transparent heavy plate.

Die Casting Machines

With the purchase of the G. & N. Mfg. Co., the Cleveland Automatic Machine Co., 2269 Ashland Road, Cleveland, has added a line of high-pressure, hydraulic die-casting machines. G. & N. machines operate safely at extremely high pressures. Patented toggle mechanism is credited with a locking pressure upwards of 800,000 lb. George A. Collier, director of Camco sales for several years, now is general sales manager of the combined divisions.

Electrode Replacements Eliminated

Advances in design of salt bath furnaces eliminate all necessity for changing electrodes, according to Upton Electric Furnace Div., 7450 Melville, Detroit. Secret of the new "sealed-Electrode" design is in the method of sealing the electrodes

through the sides of the furnace so they can be immersed in the salt or at the extreme bottom of the pot, yet none of the heated portion exposed to the air. Since about 90% of the electrode trouble is due to oxidation of the exposed heated portion, the chief source of electrode trouble is thus eliminated.

Control of Welding Heat

With three electrode groupings (low, medium and high voltage) a new calibration plate, claimed to give exactly the right heat across the arc for each electrode, has been announced by Harnischfeger Corp., Milwaukee. Calibrated in amperes, the new "Visi-Matic" plate can be used with any make of electrode. It provides for all variables of direct current amperage and voltage coincident to using today's wide range of coated electrodes, and by its single current control, reduces proper selection of welding current to the simplest form.

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Stainless steel. Allegheny Ludlum Steel Corp. Bulletin 37.

Low carbon open hearth case carburizing steel. W. J. Holliday & Co. Bulletin 38.

Aircraft Alloy Steels. Joseph T. Ryerson & Son, Inc. Bulletin 40.

Kinite alloy tool steel bar stock and its easy handling in heat treatment are described in leaflet by H. Boker & Co., Inc. Bulletin 258.

New Catalog C makes it easy to get International Nickel Co. literature, as it presents brief description and index to a wide variety of booklets. Bulletin 305.

"Graphitic Booklet" gives complete information on new, free-machining, long-wearing steel, offered by Steel & Tube Div., Timken Roller Bearing Co. Bulletin 307.

Copperweld Steel Co. announces new 48-page handbook on their tool steels. Feature of book is section on descriptions, working suggestions, and demonstration photographs for the ten Coppco tool steels. Bulletin 309.

Spark Testing Guide—a 21" x 30" wall chart—is useful in segregating tool steel scrap, unscrambling mixed stocks and checking identity of tool steel before heat treatment. Carpenter Steel Co. Bulletin 312.

HWD hot work die steel and Sterling stainless steels are described in four new leaflets by Firth-Sterling Steel Co. Bulletin 323.

New booklet gives full information on N-A-X high tensile and N-A-X 9100 Series of alloy steels. Great Lakes Steel Corp. Bulletin 328.

Spindle speed calculator is handy chart to figure machining rates on bar steels. Bliss & Laughlin, Inc. Bulletin 333.

New handbook on when, where, how and why to use various types of stainless steel is offered by Rustless Iron and Steel Corp. Bulletin 334.

Attractive new catalog describes the line of steel offered by Peninsular Steel Co. Bulletin 337.

NON-FERROUS METALS

Reynolds Metals Co. has issued two color charts showing marking for identification of wrought aluminum alloy products, rod, bar, tubing and shapes, and for aluminum alloy sheet. Bulletin 294.

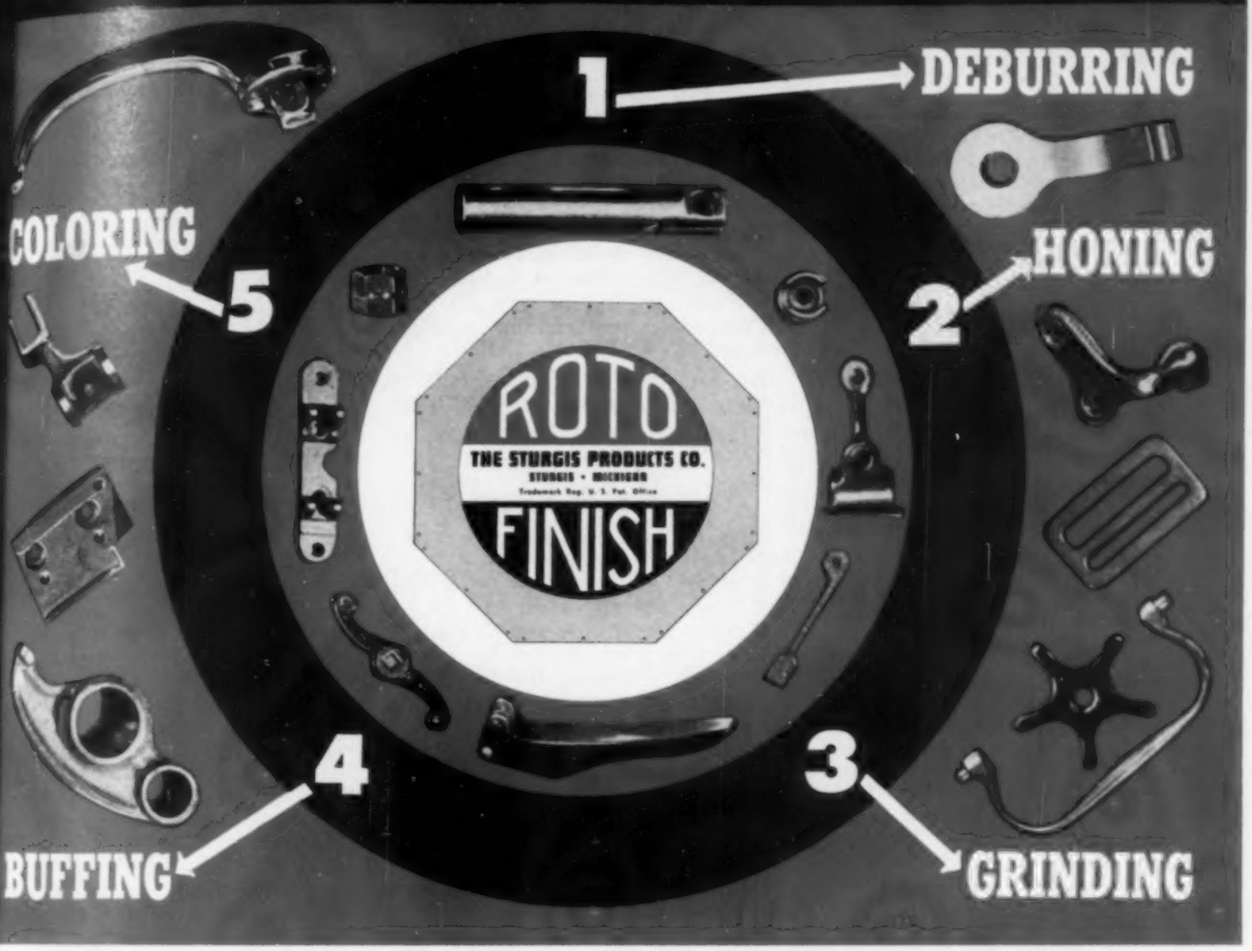
Platinum Metal Catalysts. Baker & Co., Inc. Bulletin 41.

Die casting equipment. Lester-Phoenix, Inc. Bulletin 42.

Bronze. Frontier Bronze Corp. Bulletin 44.

Use Handy Coupon on Page 482 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 482, 490, 492, 494, 496, 498, 500, 502, 504 and 508.

Roto-Finish Embraces 5 Operations for Small Parts



★ All the various sizes and shapes of parts illustrated were processed by a Roto-Finish method. This shows only the range of small parts which Roto-Finish will uniformly and economically process. Large parts weighing up to 75 pounds are being Roto-Finished in defense plants today.

★ This modern, proven method not only removes burrs, fins, tool and die marks, and other surface defects, but it also turns the parts out with a finish which is comparable to the best hand finished operations.

★ Let us demonstrate what Roto-Finish can do to help put your processing of parts on a profitable production basis.

★ Send us a number of your parts. We will Roto-Finish them without cost or obligation to you, returning them with complete data as to equipment and materials used, labor costs, time consumed, etc.

★ Compare Roto-Finish costs with the costs of your present methods.

★ The following list shows the distributors geographically located to best serve your interests:

Wagner Bros., 1249 Holden Ave., Detroit ★ F. B. Stevens, Inc., 510 Third St., Detroit ★ MacDermid, Inc., Waterbury, Conn. ★ Munning & Munning, 202 Emmett St., Newark, N. J. ★ Crown Rheostat & Sup. Co., 1910 Maypole Ave., Chicago ★ Geo. A. Stutz Mfg. Co., 1641 Carroll Ave., Chicago ★ Lasalco, Inc., 2820 La Salle Ave., St. Louis ★ Sommers Bros., 3439 N. Broadway, St. Louis ★ W. M. Fotheringham, 977 Niagara St., Buffalo ★ W. D. Forbes Co., 303 Washington Ave., N., Minneapolis ★ The Reynolds-Robson Sup. Co., 4623 Paul St., Frankford-Philadelphia.

Write for our new folder which fully describes the many advantages of Roto-Finish both in war, and peace-time.

ROTO FINISH

THE STURGIS PRODUCTS CO.

MECHANICAL FINISHING SUPPLIES AND EQUIPMENT

PHONE 717 | 203 JACOB STREET | P. O. BOX 511

STURGIS • MICHIGAN

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Handy & Harman has issued a revised edition of their general catalog on Sil-Fos and Easy-Flo brazing alloys. Bulletin 43.

Copper Alloys. American Brass Co. Bulletin 45.

Aluminum Castings. National Bronze & Aluminum Foundry Co. Bulletin 46.

Cerrosafe, a low temperature melting metal, used to accurately proofcast cavities. Cerro de Pasco Copper Corp. Bulletin 47.

Brass and bronze castings. Hammond Brass Works. Bulletin 48.

Reference on properties of lead. St. Joseph Lead Co. Bulletin 49.

6th edition of Revere Weights and Data Handbook. Revere Copper and Brass, Inc. Bulletin 296.

Catalog of brass, bronze and iron alloys. Cramp Brass and Iron Foundries Div., Baldwin Locomotive Works. Bulletin 50.

Dowmetal data book. Dow Chemical Co. Bulletin 51.

80-page Duronze Manual, well indexed for reference, presents data on high strength silicon bronzes. Bridgeport Brass Co. Bulletin 52.

Forgeable tin-free bearing metal. Mueller Brass Co. Bulletin 53.

Surface protection for magnesium. American Magnesium Corp. Bulletin 54.

Rare metals, alloys and ores. Foote Mineral Co. Bulletin 56.

Brazing Booklet. Westinghouse Elec. & Mfg. Co. Bulletin 57.

"The Story of Magnesium," illustrated booklet by the Permanente Metals Corp. Bulletin 261.

Two new Ampco Metal data sheets discuss forging Ampco to improve physical characteristics and use of Ampco for non-scratching feed fingers. Bulletin 314.

WELDING

"Sureweld" protected arc electrodes. Hollup Corp., division of National Cylinder Gas Co. Bulletin 58.

Welding Stainless. Page Steel & Wire Div., American Chain & Cable Co., Inc. Bulletin 59.

Chart explains how to select proper flux for every welding, brazing and soldering job. Krembs & Co. Bulletin 60.

Electrode quantity and welding time graph. Arcos Corp. Bulletin 61.

Oxy-acetylene welding and cutting. Linde Air Products Co. Bulletin 62.

Sciaky radial portable welder. Sciaky Brothers. Bulletin 63.

Flexarc A-C welders. Westinghouse Electric & Mfg. Co. Bulletin 64.

Data book facts on spot, seam and flash welding ferrous and non-ferrous metals and alloys. P. R. Mallory & Co., Inc. Bulletin 65.

Welding and brazing of aluminum, a new data book issued by Aluminum Co. of America. Bulletin 66.

Shield Arc electrodes. McKay Co. Bulletin 67.

New advances in arc welding equipment design. Harnischfeger Corp. Bulletin 68.

Nu-Braze No. 4, an improved silver brazing alloy. Sherman & Co. Bulletin 288.

New "200" welder is described by Allis-Chalmers in Bulletin 260.

New JR shape cutting machine is described by National Cylinder Gas Co. Bulletin 233.

New 12-page booklet tells how to fabricate fittings for welded piping by means of flame-cutting and welding. Air Reduction Co. Bulletin 234.

Atomic-hydrogen arc welding, its application and use, is described by General Electric Co. in new Bulletin 241.

Welding alloys and metals on which they should be used are shown in helpful chart form by Eutectic Welding Alloys Co. Bulletin 242.

32-page catalog describes line welding equipment offered by V tor Equipment Co. Bulletin 245.

Advantages and physical chara teristics of "No-Wear", a hard-faci material. Callite Tungsten Corp. B letin 251.

Hard Facing Alloys. Wall-Colmon Corp. Bulletin 29.

20 pages of useful information electric arc, spot, projection, atom hydrogen, gas, flash and seam wel ing of stainless steel. Republic St Corp. Bulletin 306.

New 500 lb. capacity welding p sitioner for light welding jobs is d scribed by Ransome Machinery (Bulletin 313.

Two new hard-facing alloys fu nished as welding rods for applic tion by Oxy-Acetylene process a described by the Stoody Co. in Bu letin 325.

TESTING & CONTROL

SR-4 strain gage and illustratio of its many uses. Baldwin Sout wark. Bulletin 70.

New book contains wealth of pra tical, usable information on indu trial inspection by x-ray. Westin house Electric & Mfg. Co. Bulletin 7

X-Ray Diffraction Unit. Gener Electric X-ray Corp. Bulletin 72.

Metallurgical polishing equipme by Tracy C. Jarrett. Bulletin 295.

Radiographic identification of ne atives with lead markers. H. W Knight & Son, Inc. Bulletin 74.

Electric heaters and controls fo industrial and laboratory. Americ Instrument Co. Bulletin 75.

Carbon-Meter for rapidly dete mining carbon at the furnace. E Leitz, Inc. Bulletin 264.

New 29-page catalog — Microm Electric Control — has just been i sued by Leeds & Northrup Co. Bu letin 76.

Inspection of non-magnetic meta with the new Zyglo method. Magn flux Corp. Bulletin 78.

Use Handy Coupon on Page 482 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 482, 486, 492, 494, 496, 498, 500, 502, 504 and 508.

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Industrial radiography with radium. Canadian Radium & Uranium Corp. Bulletin 79.

Potentiometer temperature indicators. Foxboro Co. Bulletin 82.

Portable Brinell hardness tester and folding Brinell microscope. Andrew King. Bulletin 85.

Gage blocks, comparators, projectors. George Scherr Co. Bulletin 83.

Pyrometer Controller. Illinois Testing Laboratories, Inc. Bulletin 84.

Universal testing machines and typical uses. Riehle Testing Machine Div., American Machine and Metals, Inc. Bulletin 86.

Slomin high speed electrolyti analyzers and other metallurgic laboratory equipment. E. H. Sarge & Co. Bulletin 87.

Surface Analyzer. Brush Develo ment Company. Bulletin 88.

Micro-Optical Pyrometers. Pyro eter Instrument Co. Bulletin 89.

Dillon tensile tester and the Dill dynamometer. W. C. Dillon & C Bulletin 91.

Gas analysis. Burrell Technic Supply Co. Bulletin 92.

Industrial thermocouples. Arkl S. Richards Co. Bulletin 93.

Optical Aids. Bausch & Lomb O tical Co. Bulletin 94.

Coleman universal spectrophoto eter. Wilkens-Anderson Co. Bull tin 95.

Metallographic polishing powde Conrad Wolff. Bulletin 96.

Metallurgical Equipment. Adol I. Buehler. Bulletin 97.

Hardness testing equipment. Wi son Mechanical Instrument Co., In Bulletin 98.

Identometer for rapid identific tion of steel. Dravo Corp. Bullet 267.

New condensed catalog gives pric and descriptions of instruments o fered by Wheelco Instruments C Bulletin 268.

Eberbach micro hardness tester illustrated and described in ne booklet by Eberbach & Son Co. Bu letin 269.

Thermocouple selector switch for pyrometer applications are d scribed in new leaflet by Lewis E gineering Co. Bulletin 229.

Moisture determinations of a wi range of materials with new Moistu Teller instrument are described i new leaflet by Harry W. Dietert C Bulletin 299.

New flexible film holder for indu trial radiography is illustrated an described in leaflet by Picker X-R Corp. Bulletin 300.

Stresscoat, a method of analyzi distribution, direction and value local strains in any structure b means of formation of character tic crack patterns in a brittle coati applied to its structure, is describe in leaflets issued by Magnaflux Cor Bulletin 301.

Type 2 automatic valve operato widely used mechanism designed f industrial operation of valves, dam ers, or other control devices, are d scribed in new leaflet by Automat Temperature Control Co. Bullet 317.

Attractive, illustrated booklet d scribes Clark Instrument's precisi hardness tester. Bulletin 318.

Turbo-Compressor data boo shows how to calculate compresse air systems for a dozen different ap plications. Spencer Turbine Co. Bu letin 329.

Use Handy Coupon on Page 482 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 482, 486, 490, 494, 496, 498, 500, 502, 504 and 508.

WHAT'S NEW

IN MANUFACTURERS' LITERATU[RE]

Pyrometer control of high spe[ed] salt baths is described in new boo[k]let by Brown Instrument Co. Bull[e]tin 324.

40-page booklet contains usef[ul] technical information on thermo[m]etry and thermometers. Bristol C[o.] Bulletin 321.

"Radiography of Materials" is title [of] new book on industrial radiograph[y.] Eastman Kodak Co. Bulletin 331.

New file folder service bulletin [on] Weaver Furnace Atmosphere Ind[i]cator. Claud S. Gordon Co. Bullet[in] 332.

HEATING • HEAT TREAT[-] MENT

36-page catalog illustrates Kol[d-] Hold line of thermal, sub-zero an[d] stratosphere processing and testi[ng] machines. Kold-Hold Mfg. Co. Bull[e]tin 99.

Homo method for nitriding is d[e]scribed and illustrated in new 1[…] page catalog by Leeds & Northru[p.] Bulletin 100.

Lithco, the chemically-neutral he[at] treating process, and Lithcarb, th[e] process for fast, bright gas-carburi[z]ing. Lithium Corp. Bulletin 101.

Internally heated salt bath furnac[es] and pots. Upton Electric Furna[ce] Div. Bulletin 102.

Induction heating. Induction Hea[t]ing Corp. Bulletin 103.

S.F.E. Standard Industrial furnac[e] catalog. Standard Fuel Engineerin[g] Co. Bulletin 104.

Easy-selection charts on ga[s] burning equipment. National Ma[-] chine Works. Bulletin 105.

8-page pictorial bulletin describe[s] the heat treating service of Conti[-] nental Industrial Engineers, Inc. Bu[l]letin 107.

Hagan rotary forging furnaces ar[e] described in bulletin by George [J.] Hagan Co. Bulletin 108.

Comprehensive, 100-page textboo[k] describes constructional feature[s,] capacities, operation and instr[u]mentation of nitriding furnace[s.] Nitralloy Corp. Bulletin 289.

Centrifugal blowers and exhaus[t]ers. Roots Connersville Blower Corp[.] Bulletin 270.

Furnaces for heat treatment of alu[-] minum, magnesium and their alloy[s.] Lindberg Engineering Co. Bulleti[n] 271.

Heavy duty high temperature allo[y] steel fans are described by Despatc[h] Oven Co. Bulletin 272.

"The Trend Is Toward Salt" i[s] title of interesting leaflet showin[g] several examples of heat treatmen[t.] Ajax Electric Co. Bulletin 274.

Use Handy Coupon on Page 482 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 482, 486, 490, 492, 496, 498, 500, 502, 504 and 508.

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Electric Furnaces. Ajax Electrothermic Corp. Bulletin 106.

Gas, oil and electric heat treating and carburizing furnaces. Holcroft & Co. Bulletin 114.

Rotary Hearth Furnaces. Lee Wilson Sales Corp. Bulletin 290.

Industrial furnaces, equipment for bright annealing stainless steels and ammonia dissociation equipment. Drever Co. Bulletin 115.

Industrial ovens, rod bakers, welding rod ovens, furnaces. Carl-Mayer Corp. Bulletin 116.

Full muffle and other heat treating furnaces described in catalog by Charles A. Hones, Inc. Bulletin 117.

56-page vest pocket data book on heat treating practices and procedures. Chicago Flexible Shaft Co. Bulletin 118.

Non-metallic Electric Heating Elements. Globar Div., Carborundum Co. Bulletin 119.

24-page catalog describes gas, oil and electric Holden heat treating pot furnaces, and baths. A. F. Holden Co. Bulletin 120.

Modern electric furnaces for heat treating. Harold E. Trent Co. in new Bulletin 121.

Control of temperatures of quenching baths. Niagara Blower Co. Bulletin 122.

Molten Salt Baths. E. I. DuPont de Nemours & Co., Inc., Electrochemicals Department. Bulletin 123.

Tocco hardening, brazing, annealing and heating machines. Ohio Crankshaft Co. Bulletin 124.

Kleen-well oil strainers for quench oil cooling systems. Bell & Gossett Co. Bulletin 125.

Unichrome alkaline copper processes for improvement of selective hardening and deep drawing of steel. United Chromium, Inc. Bulletin 127.

"Pulverized Coal, the Victory Fuel". Amsler-Morton Co. Bulletin 129.

Heat treating furnaces. Johnston Mfg. Co. Bulletin 130.

Drycolene. General Electric furnace atmosphere. Bulletin 131.

Dual-Action quenching oil. Gulf Oil Co. Bulletin 132.

Handling cylinder anhydrous a monia for metal treaters. Arm Ammonia Works. Bulletin 128.

Industrial Furnaces. W. S. Ro well Co. Bulletin 133.

Certain Curtain Furnaces. C. Hayes, Inc. Bulletin 134.

Air-Oil Ratiotrol for proportion flow of fuel oil and air to oil burne North American Mfg. Co. Bulle 135.

Blue Print for Industry is title new handbook presenting oven en neering information. Industrial O Engineering Co. Bulletin 136.

Interesting and helpful inform tion available on the use of al pots for heating operation by Swedish Crucible Steel Co. Bulle 137.

Two new bulletins on vertical c burizers and on carbonia fini American Gas Furnace Co. Bul tin 139.

Van Norman induction heati units. Van Norman Machine Tool C Bulletin 144.

Use Handy Coupon on Page 482 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 482, 486, 490, 492, 494, 498, 500, 502, 504 and 508.

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Gas-air premix machine. Eclipse Fuel Engineering Co. Bulletin 138.

Low temperature equipment for aging, shrinking, etc. Deepfreeze Div., Motor Products Corp. Bulletin 140.

Controlled atmosphere furnace for heat treatment of tool and alloy steels. Delaware Tool Steel Corp. Bulletin 141.

Furnaces. Tate-Jones Co. Bulletin 142.

Industrial Carburetors. C. M. Kemp Mfg. Co. Bulletin 143.

High and low temperature direct fired furnaces. R-S Products Corp. Bulletin 146.

Heat treating, brazing and melting of ferrous and non-ferrous metals. Lepel High Frequency Laboratories, Inc. Bulletin 147.

Vertical Furnace. Sentry Co. Bulletin 148.

Conveyor Furnaces. Electric Furnace Co. Bulletin 149.

New Electric Furnace. American Electric Furnace Co. Bulletin 150.

Newly developed salt bath material for use in Martempering process. E. F. Houghton & Co. Bulletin 151.

Electric Furnaces for laboratory and production heat treatment. Hoskins Mfg. Co. Bulletin 152.

Furnace Experience. Flinn & Dreffein Co. Bulletin 153.

Flame-type mouth and taper annealing machine for steel cartridge cases. Morrison Engineering Corp. Bulletin 154.

Dehumidifier. Pittsburgh Lectrodryer Corp. Bulletin 155.

No-Carb, a liquid paint for prevention of carburization or decarburization. Park Chemical Co. Bulletin 156.

Furnaces. Dempsey Industrial Furnace Corp. Bulletin 157.

High Temperature Fans. Michiana Products Corp. Bulletin 158.

16-page engineering and data booklet on proportioning oil burners. Hauck Mfg. Co. Bulletin 160.

Pictorial bulletin describes furnaces for heat treating, normalizing, annealing, forging. Vulcan Corp. Bulletin 161.

Modern malleableizing in Surface Combustion furnaces is described in illustrated leaflet. Bulletin 308.

Protective combusted atmospheres in Hevi Duty Electric Co. furnaces are discussed in 12-page Bulletin 316.

Use Handy Coupon on Page 482 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 482, 486, 490, 492, 494, 496, 500, 502, 504 and 508.

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Infra-red gas burners and their advantages are described in new booklet by Burdett Mfg. Co. Bulletin 111.

New catalog describes complete line of heat treating materials offered by Heatbath Corp. Bulletin 322.

Laboratory and tool room furnace requiring no blower is described by Mahr Mfg. Co. in new Bulletin 327.

REFRACTORIES & INSULATION

Insulating firebrick. Babcock & Wilcox Co. Bulletin 162.

Cromox, new protective refractory coating material for prolonging life of firebrick, insulating firebrick, and castable refractories. Federal Refractories Corp. Bulletin 163.

Heavy Duty Refractories. Norton Co. Bulletin 164.

Super Refractories catalog. Carborundum Co. Bulletin 165.

Interesting data sheets on Therm-O-Flake insulating bricks and coatings. Illinois Clay Products Co. Bulletin 298.

P. B. Sillimanite refractories. Chas. Taylor Sons Co. Bulletin 166.

Conductivity and heat transfer charts. Johns-Manville. Bulletin 167.

Ramix bottom for basic open hearth furnaces. Basic Refractories, Inc. Bulletin 168.

Brickseal refractory coating. Brickseal Refractory Co. Bulletin 169.

D-E insulating materials and their application are described in new data booklet by Armstrong Cork Co. Bulletin 208.

Corhart Electrocast Refractories for the melting and refining of metals are described by Corhart Refractories Co. Bulletin 209.

FINISHING • PLATING • CLEANING

Roto-Finish equipment for deburring, buffing, polishing and coloring. Sturgis Products Co. Bulletin 170.

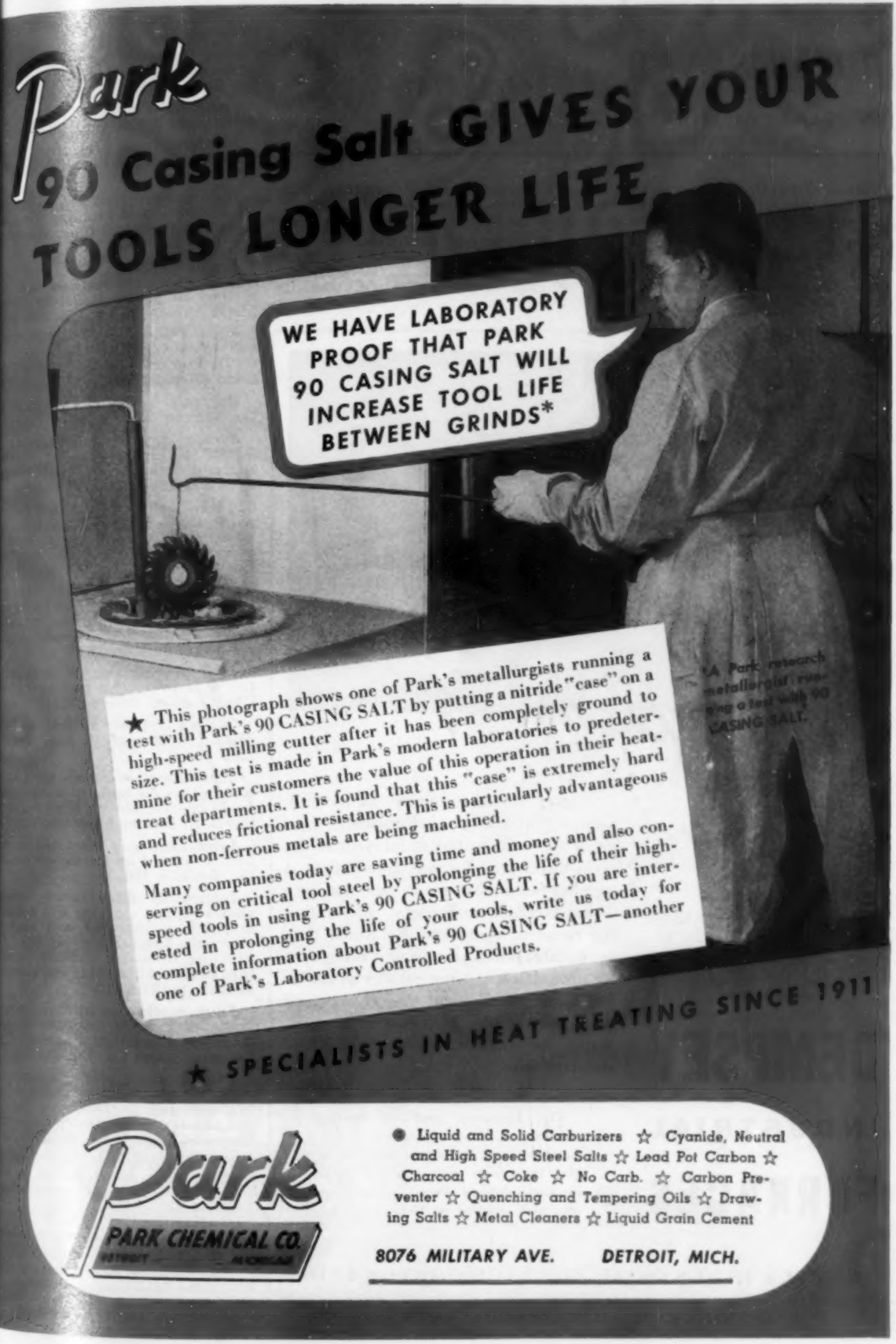
A protective, deep black finish to steel. Heatbath Corp. Bulletin 171.

Alvey Ferguson Co. shows how various product washing problems were solved. Bulletin 172.

Four new booklets describe blackening processes for metals. Enthone Co. Bulletin 276.

Pickling. Wm. M. Parkin Co. Bulletin 174.

Use Handy Coupon on Page 482 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 482, 486, 490, 492, 494, 496, 498, 502, 504 and 508.


Park
90 Casing Salt GIVES YOUR TOOLS LONGER LIFE
WE HAVE LABORATORY PROOF THAT PARK 90 CASING SALT WILL INCREASE TOOL LIFE BETWEEN GRINDS*
*A Park research metallurgist running a test with 90 CASING SALT.
★ This photograph shows one of Park's metallurgists running a test with Park's 90 CASING SALT by putting a nitride "case" on a high-speed milling cutter after it has been completely ground to size. This test is made in Park's modern laboratories to predetermine for their customers the value of this operation in their heat-treat departments. It is found that this "case" is extremely hard and reduces frictional resistance. This is particularly advantageous when non-ferrous metals are being machined.
Many companies today are saving time and money and also conserving on critical tool steel by prolonging the life of their high-speed tools in using Park's 90 CASING SALT. If you are interested in prolonging the life of your tools, write us today for complete information about Park's 90 CASING SALT—another one of Park's Laboratory Controlled Products.
★ SPECIALISTS IN HEAT TREATING SINCE 1911
Park
PARK CHEMICAL CO.
DETROIT MICHIGAN
● Liquid and Solid Carburizers ☆ Cyanide, Neutral and High Speed Steel Salts ☆ Lead Pot Carbon ☆ Charcoal ☆ Coke ☆ No Carb. ☆ Carbon Preventer ☆ Quenching and Tempering Oils ☆ Drawing Salts ☆ Metal Cleaners ☆ Liquid Grain Cement
8076 MILITARY AVE. DETROIT, MICH.

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Motor-Generators for electroplating and other electrolytic processes. Columbia Electric Mfg. Co. Bulletin 173.

Detrex metal cleaning machines, metal cleaning chemicals and processing equipment. Detrex Corporation. Bulletin 175.

Electrochemical Descaling. Bullard-Dunn Process Div., Bullard Co. Bulletin 212.

Methods and equipment for electro-plating are described in illustrated booklet of U. S. Galvanizing & Plating Equipment Corp. Bulletin 303.

Airless Rotoblast. Pangborn Corp Bulletin 176.

Rust inhibiting wax coatings fo protection of metal. S. C. Johnson Son, Inc. Bulletin 180.

Cadmium Plating. E. I. duPo deNemours & Co., Inc. Bulletin 17

Tumbling and cleaning. Glob Stamping and Machine Co. Bulleti 179.

Well-rounded and helpful catalo on finishing and cleaning has bee issued by Frederick Gumm Chemic Co., Inc. Bulletin 292.

Resilon corrosion-resistant tan linings and applications are d scribed in 8-page leaflet by Unit States Stoneware Co. Bulletin 291.

Anodizing and plating equipmen Lasalco, Inc. Bulletin 211.

"Indium and Indium Plating". In dium Corp. of America. Bulletin 1

Degreasers. Phillips Manufacturi Co. Bulletin 178.

Service report describes use Oakite machining, drawing, degre ing and descaling materials. Oaki Products, Inc. Bulletin 210.

Lithoform method for makin paint stick to galvanized iron a other zinc or cadmium surfaces described in new leaflet by Americ Chemical Paint Co. Bulletin 326.

New 4-page booklet describes a illustrates new American Tabl-Spr Metal Washing Machine manufa tured by American Foundry Equi ment Co. Bulletin 336.

Jetal process and its characteri tics as a protective coating. Alro Chemical Co. Bulletin 213.

Casting cleaning methods in fou dries. N. Ransohoff, Inc. Bulleti 214.

Catalog section on new sheet Kor seal linings for tanks of welded ste wood or concrete has been issued b the B. F. Goodrich Co. Bulletin 11

Lead plating is discussed in ne booklet issued by Harshaw Chemic Co. Bulletin 109.

Interesting, illustrated catalo shows typical cleaning and finishi machines engineered and built b Howard Engineering & Mfg. C Pickling, tumbling, washing, quenc ing, drying, burnishing equipment shown. Bulletin 110.

Four types of solvent degrease and cleaners are described in ne leaflet by Technical Processes Di Colonial Alloys Co. Bulletin 230.

72-page metal cleaning handboo provides organized means of sele ing cleaning materials, methods use and types of washing equipme Magnus Chemical Co. Bulletin 231.

Three electronic controllers f plating tanks are described in ne folder by Plating Processes Cor Bulletin 235.

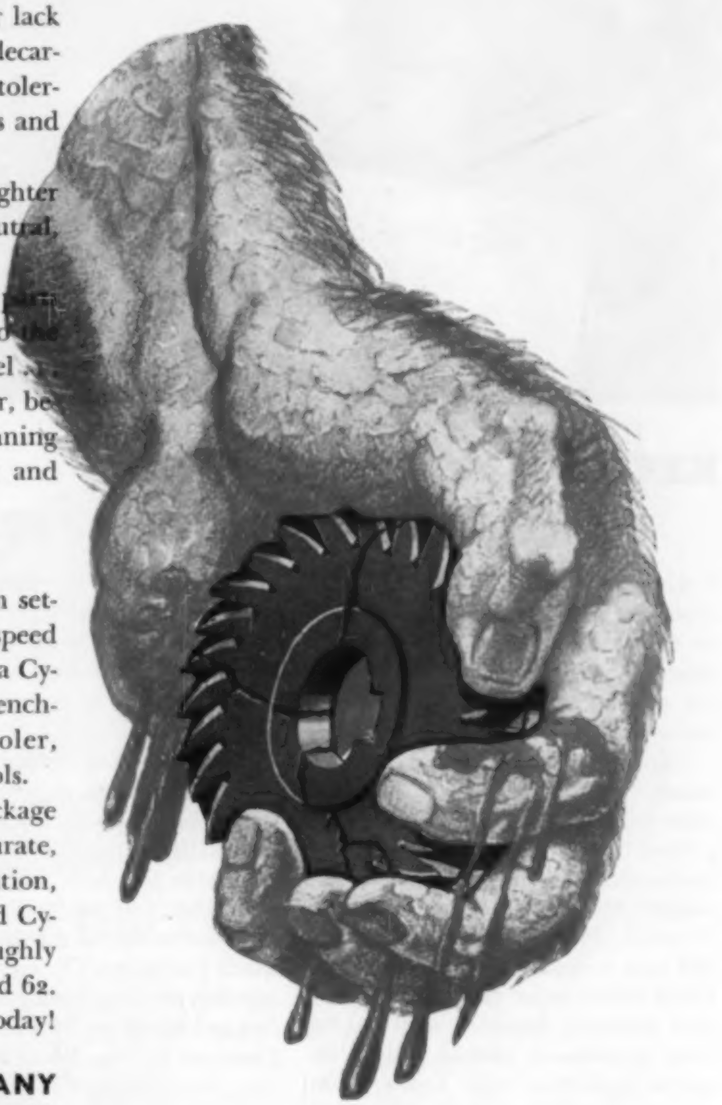
Use Handy Coupon on Page 482 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 482, 486, 490, 492, 494, 496, 498, 500, 504 and 508.

Is *Murder* being plotted in your toolroom heat treat department?

OFTTIMES the death of a tool or die is unwittingly plotted in the sweat and flame of the heat treating department. Scale kills the tool for lack of uniform hardness. The "soft skin" of decarburization robs the surface of necessary tolerances. Carburization leads to fatigue cracks and part failure.

You *can* put a stop to the unnecessary slaughter of tools and dies. You can do it with the neutral, controlled atmosphere of Hydryzing.

The clean uniform hardness of Hydryzed parts insures the precision planning you put into the job . . . it justifies the careful selection of steel . . . enhances the craftsmanship of the toolmaker, besides saving you the expense of costly cleaning operations such as sandblasting, pickling and polishing.



HEAT TREATING IN A PACKAGE

LINDBERG can supply a complete toolroom setup, including a preheat furnace, high speed furnace (both with Hydryzing atmosphere), a Cyclone Toolroom Tempering Furnace, and quenching equipment complete with tank, cooler, circulating pump, and temperature controls.

Lindberg toolroom heat treating in a package gives you clean, uniform hardness with accurate, low-cost tempering. The advantages, operation, sizes, and types of Hydryzing hardening and Cyclone tempering furnaces are more thoroughly explained and illustrated in Bulletins 94 and 62. Insure your tool and die production. Write today!

LINDBERG ENGINEERING COMPANY
2448 West Hubbard Street • Chicago 12

LINDBERG FURNACES

ARMY E NAVY

SUPER-CYCLONE for hardening, normalizing, annealing, tempering
CYCLONE for accurate, low-cost tempering and nitriding
HYDRYZING for scale-free and decarb-free hardening

WHAT'S NEW IN MANUFACTURERS' LITERATURE

New vapor cleaner equipment of Circo Products Company is described in Bulletin 238.

Discussion of anodizing, chromatizing and phosphatizing in illustrated 60-page book has been issued by Turco Products, Inc. Bulletin 243.

MELTING • CASTING • MILL OPERATIONS

Crucibles for brass, copper, aluminum and magnesium industries. Electro Refractories and Alloys Corp. Bulletin 183.

Ingot Production. Gathmann Engineering Co. Bulletin 185.

Manganese-Titanium Steels. Titanium Alloy Mfg. Co. Bulletin 184.

"Electromet Products and Service". Electro Metallurgical Co. Bulletin 186.

Chrom-X for steel mill and foundry. Chromium Mining & Smelting Co. Bulletin 187.

Lectromelt Furnaces. Pittsburgh Lectromelt Furnace Corp. Bulletin 188.

Electric Furnaces. Detroit Electric Furnace Div., Kuhlman Electric Co. Bulletin 189.

Stroman crucible melting furnaces for aluminum and magnesium are described in leaflet by Stroman Furnace & Engineering Co. Bulletin 277.

Operating Features, capacities, charging methods of the Heroult electric furnace. American Bridge Co. Bulletin 215.

How Research Has Produced developments that make the side-blow converter process desirable as a source of high temperature metal. Whiting Corp. Bulletin 216.

Chart for the correction of brasses for zinc loss should interest foundrymen. Foundry Services, Inc. Bulletin 217.

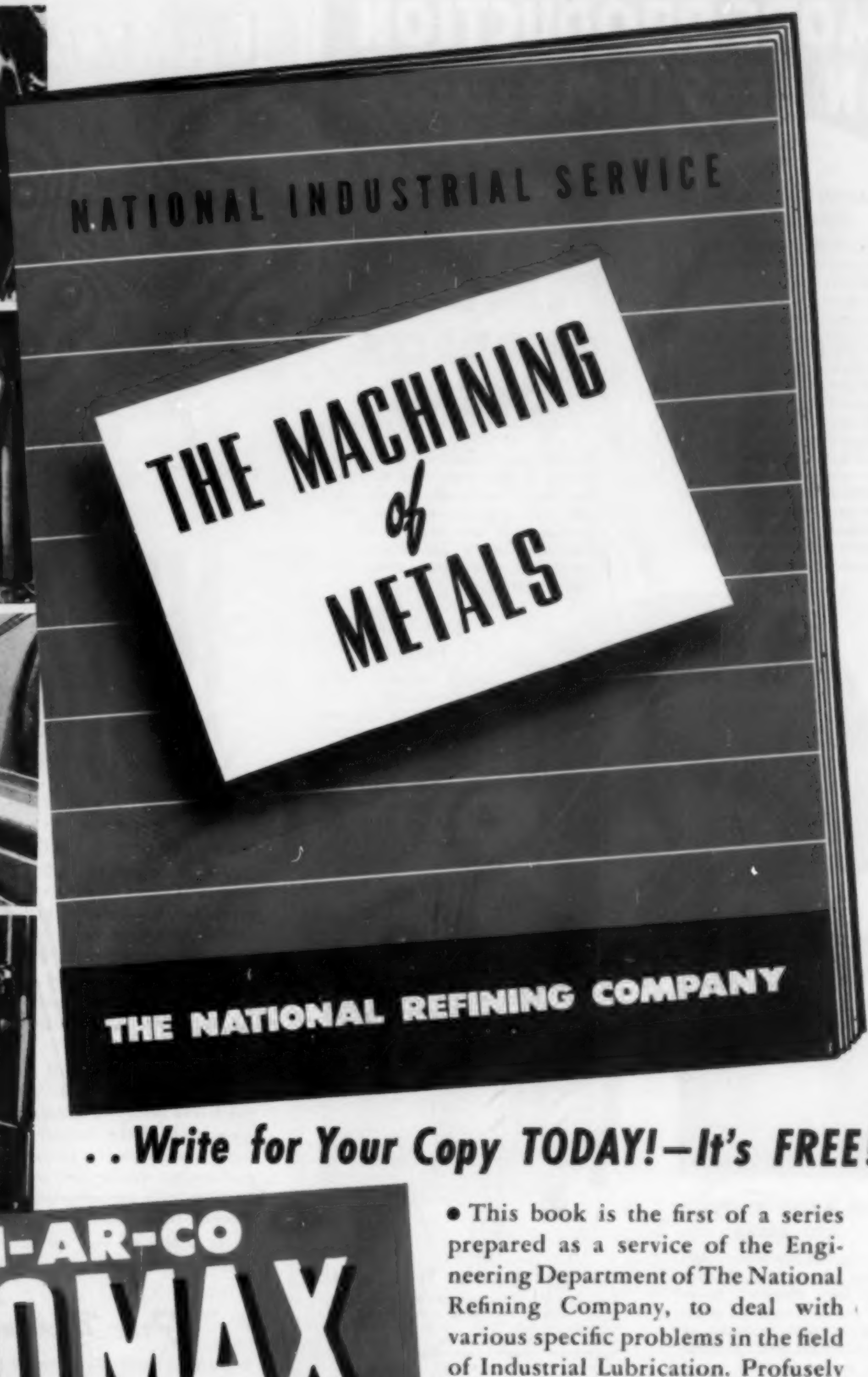
Coke oven plant construction and development in 1942 is described and illustrated in 12-page pamphlet by the Koppers Co. Bulletin 232.

"Fisher Magnesium Scrapbook". Fisher Furnace Co. Bulletin 281.

Attractive booklet describes growth, facilities and offers valuable alloy hints. Niagara Falls Smelting & Refining Corp. Bulletin 246.

Vertical centrifugal casting machine for production of ferrous and nonferrous castings is described by Centrifugal Casting Machine Co. in Bulletin 315.

Use Handy Coupon on Page 482 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 482, 486, 490, 492, 494, 496, 498, 500, 502 and 508.



NATIONAL INDUSTRIAL SERVICE
THE MACHINING of METALS
THE NATIONAL REFINING COMPANY

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Interesting, descriptive leaflet on metal reclaiming mill offered by Dreisbach Engineering Corp. Bulletin 284.

ENGINEERING • APPLICATIONS • PARTS

Chace manganese alloy No. 772 in sheets, strips, rod and special shapes described by W. M. Chace Co. Bulletin 190.

Centrifugal castings. Shenango-Penn Mold Co. Bulletin 191.

12-page booklet describes many specialties of Summerill Tubing Co. Bulletin 282.

Duraspun Centrifugal Castings. Duraloy Co. Bulletin 194.

Electrical, corrosion and heat resisting alloys in rod, wire, ribbon and strip forms. Wilbur B. Driver Co. Bulletin 192.

Carburizing Boxes. Pressed Steel Co. Bulletin 193.

Cast bronze, sleeve type standardized bearings. Bunting Brass & Bronze Co. Bulletin 195.

Nichrome and alloy castings. Driver-Harris Co. Bulletin 283.

Meehanite Castings. Meehanite Research Institute. Bulletin 196.

X-Ray Inspected Castings. Electro Alloys Co. Bulletin 197.

Metal Baskets. W. S. Tyler Co. Bulletin 198.

Steel Castings. Chicago Steel Foundry Co. Bulletin 199.

Heat Resisting Alloys. General Alloys Co. Bulletin 200.

Pipes and Tubes. Michigan Steel Casting Co. Bulletin 201.

Bimetals and Electrical Contacts. The H. A. Wilson Company. Bulletin 202.

Cr-Ni-Mo Steels. A. Finkl & Sons Co. Bulletin 203.

Industrial baskets, crates, trays and fixtures. Rolock, Inc. Bulletin 204.

Seamless pressed steel heat treating containers. Eclipse Fuel Engineering Co. Bulletin 205.

48-page catalog on manganese steel. American Manganese Steel Div., American Brake Shoe Co. Bulletin 293.

New process of tube spinning developed by Wolverine Tube Div., Calumet & Hecla Consolidated Copper Co., is described in brochure just released. Bulletin 287.

An engineer's handbook on electrical contacts. Fansteel Metallurgical Corp. Bulletin 218.

Cooper standard alloys. Cooper Alloy Foundry Co. Bulletin 206.

Alloy Castings. Ohio Steel Foundry Co. Bulletin 207.

Manual on welded steel tubing for heat exchanger and condenser use has been issued by Formed Steel Tube Institute. Bulletin 286.

Just released by Atlas Brass Foundry is an 84-page catalog listing sizes and prices of hundreds of finished bronze bushings and porous oil-retaining bearings. Bulletin 219.

Flanges and other drop forgings. Ladish Drop Forge Co. Bulletin 221.

Finding list and list of sources of alloy metals. Hobart Brothers Co. Bulletin 222.

Powder metal oil-retaining porous bronze bearings are described and illustrated in new booklet by Bound Brook Oil-less Bearing Co. Bulletin 279.

Ledaloyl, self-lubricating bearings. Johnson Bronze Co. Bulletin 223.

Metal Powders. Metals Disintegrating Co. Bulletin 224.

Corrosion and heat resistant alloys. Lebanon Steel Foundry. Bulletin 225.

Lead-base metals. Magnolia Metal Co. Bulletin 226.

Oilite precision oil cushion-bronze bearings and other powder metal bar, plate and strip stocks are comprehensively described in 140-page catalog issued by Amplex Div., Chrysler Corp. Bulletin 227.

Many advantages of metal spinning are described and illustrated in leaflet issued by Milwaukee Metal Spinning Co. Bulletin 113.

Many applications and savings through use of drop forgings are shown in Drop Forging Topics, issued by Drop Forging Assn. Bulletin 240.

Handy file leaflet describes wire baskets, fixtures, etc., offered by W. S. Tyler Co. Bulletin 302.

24-page catalog is guide to properties and use of Monsanto plastics. Monsanto Chemical Co. Bulletin 319.

Details of new Chemicast process for small brass parts will be supplied by Chemicast Div., Whip-Mix Corp. Bulletin 330.

Use Handy Coupon on Page 482 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 482, 486, 490, 492, 494, 496, 498, 500, 502 and 504.

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

METAL WORKING • FABRICATION

Automatic profilers and hydraulic benders are described in catalogs issued by the Pines Engineering Co. Bulletin 344.

Clark 3-blade adjustable hole cutter and 3-blade adjustable surface facer are described in new illustrated leaflet by Robert H. Clark Co. Bulletin 348.

Powdered metal presses producing millions of metal parts illustrated in catalog by Kux Machine Co. Bulletin 1.

Forging presses. Ajax Mfg. Co. Bulletin 2.

Horizontal extrusion presses. Hydropress, Inc. Bulletin 3.

36-page pictorial story of the Cecostamp. Cambersburg Engineering Co. Bulletin 4.

Cutting Oils. Cities Service Oil Co. Bulletin 5.

Cutting Oil Handbook. D. A. Stuart Oil Co. Bulletin 6.

Presses for Powder Metallurgy. F. J. Stokes Machine Co. Bulletin 7.

Properties and uses of cutting oils. Gulf Oil Corp. Bulletin 8.

Information and data on straightening press. Anderson Bros. Mfg. Co. Bulletin 10.

Forty different ways to cut machining costs. Continental Machines, Inc. Bulletin 11.

Properties, applications and use of hard-facing rods. Coast Metals, Inc. Bulletin 249.

Surface coated abrasive belts. Minnesota Mining & Mfg. Co. Bulletin 12.

Presses for the metal working and process industries. Hydraulic Press Mfg. Co. Bulletin 20.

Handbook on aircraft riveting. Cherry Rivet Company. Bulletin 14.

Savings in oils, tool bits, grinding wheels. Sparkler Mfg. Co. Bulletin 15.

New catalog illustrates standard, non-standard, and special tools, shows prices of tools and blanks. Kennametal, Inc. Bulletin 250.

Mounted wheels, Handee and Hi-Power tools. Chicago Wheel & Mfg. Co. Bulletin 21.

20-page booklet on cutting fluids. Tide Water Associated Oil Co. Bulletin 252.

Air tools in steel mills and foundries are pictured in new booklet by Ingersoll-Rand. Bulletin 255.

Parsons oval bag dust arrestors are described and 12 advantages listed in folder issued by Parsons Engineering Corp. Important advantage is reclamation of valuable dust. Bulletin 228.

New Weel Speed Table will interest those engaged in polishing and buffing. Recommended speeds are shown in red. Divine Brothers Co. Bulletin 310.

Key to efficient automatic finishing is described in new 8-page illustrated bulletin showing Hammond Machinery Builders' rotary table automatics. Bulletin 311.

Big, comprehensive catalog illustrates line of power presses offered by Minster Machine Co. Bulletin 320.

Complete and valuable study of "Machining of Metals", including chip formation, is offered by National Refining Co. Bulletin 335.

FERROUS METALS

Republic Steel Corp.'s second edition of National Emergency Steels tells you all about these new steels. Bulletin 345.

Page after page of useful technical data and reference tables on tool steels. Latrobe Electric Steel Co. Bulletin 367.

Machinery steel selector has been issued by the Elastuf group which includes Horace T. Potts, Brown Wales and Beals, McCarthy & Rogers. Bulletin 256.

Aircraft steels, bearing steels. Rotary Electric Steel Co. Bulletin 24.

Steel Data Sheets. Wheelock, Lovejoy & Co. Bulletin 25.

Molybdenum wrought steels. Molybdenum Corp. of America. Bulletin 26.

Chemical analyses, shapes and sizes of Joslyn stainless steel products are presented in extras and deductions booklet just issued by Joslyn Mfg. and Supply Co. Bulletin 297.

Use Handy Coupon Below for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 578, 580, 582, 584, 586, 588 and 592.

Metal Progress 7301 Euclid Ave., Cleveland 3, Ohio — October, 1943

Send me the Literature I have indicated below.

Name .... Title ....

Company .... Address ....

(Students—please write direct to manufacturers).

Check or circle the numbers referring to literature described on these 8 pages.

1	31	56	84	108	135	156	180	204	243	281	315	338	358
2	33	57	85	109	136	158	182	206	245	284	316	339	359
3	35	58	86	110	137	160	183	207	246	288	318	340	360
4	37	59	88	112	138	161	184	208	249	290	319	341	361
5	38	60	89	114	139	162	185	209	250	291	320	342	362
6	40	62	91	115	140	163	186	210	251	292	321	343	363
7	41	64	93	116	141	164	187	212	252	294	322	344	364
8	42	65	94	117	142	165	188	213	255	296	323	345	365
10	43	66	95	118	143	167	189	215	256	297	324	346	366
11	44	67	96	119	144	168	190	217	258	298	325	347	367
12	45	68	97	120	146	169	192	221	260	299	327	348	368
14	46	70	98	121	147	170	193	226	261	300	328	349	369
15	47	71	99	122	148	171	194	228	264	301	329	350	370
20	48	72	100	123	149	172	196	230	267	305	330	351	371
21	49	75	101	124	150	173	197	232	268	307	331	352	372
24	50	76	102	128	151	174	199	233	269	310	332	353	373
25	51	78	103	131	152	175	200	234	270	311	333	354	374
26	52	79	105	132	153	176	201	240	271	312	334	355	
29	53	82	106	133	154	177	202	241	276	313	335	356	
30	54	83	107	134	155	179	203	242	277	314	337	357	

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Free Machining Steels. Monarch Steel Co. Bulletin 30.

Tool Steels. Bethlehem Steel Co. Bulletin 31.

Enameling iron sheets. Inland Steel Co. Bulletin 33.

Loose-leaf reference book on molybdenum steels. Climax Molybdenum Co. Bulletin 35.

Stainless steel. Allegheny Ludlum Steel Corp. Bulletin 37.

Low carbon open hearth case carburizing steel. W. J. Holliday & Co. Bulletin 38.

Aircraft Alloy Steels. Joseph T. Ryerson & Son, Inc. Bulletin 40.

Kinite alloy tool steel bar stock and its easy handling in heat treatment are described in leaflet by H. Boker & Co., Inc. Bulletin 258.

New Catalog C makes it easy to get International Nickel Co. literature, as it presents brief description and index to a wide variety of booklets. Bulletin 305.

"Graphitic Booklet" gives complete information on new, free-machining, long-wearing steel, offered by Steel & Tube Div., Timken Roller Bearing Co. Bulletin 307.

Spark Testing Guide—a 21" x 30" wall chart—is useful in segregating tool steel scrap, unscrambling mixed stocks and checking identity of tool steel before heat treatment. Carpenter Steel Co. Bulletin 312.

HWD hot work die steel and Sterling stainless steels are described in four new leaflets by Firth-Sterling Steel Co. Bulletin 323.

New booklet gives full information on N-A-X high tensile and N-A-X 9100 Series of alloy steels. Great Lakes Steel Corp. Bulletin 328.

Spindle speed calculator is handy chart to figure machining rates on bar steels. Bliss & Laughlin, Inc. Bulletin 333.

New handbook on when, where, how and why to use various types of stainless steel is offered by Rustless Iron and Steel Corp. Bulletin 334.

Attractive new catalog describes the line of steel offered by Peninsular Steel Co. Bulletin 337.

NON-FERROUS METALS

Reynolds Metals Co. has issued two color charts showing marking for identification of wrought aluminum alloy products, rod, bar, tubing and shapes, and for aluminum alloy sheet. Bulletin 294.

Platinum Metal Catalysts. Baker & Co., Inc. Bulletin 41.

Die casting equipment. Lester-Phoenix, Inc. Bulletin 42.

Bronze. Frontier Bronze Corp. Bulletin 44.

Handy & Harman has issued a revised edition of their general catalog on Sil-Fos and Easy-Flo brazing alloys. Bulletin 43.

Copper Alloys. American Brass Co. Bulletin 45.

Aluminum Castings. National Bronze & Aluminum Foundry Co. Bulletin 46.

Cerrosafe, a low temperature melting metal, used to accurately proof-cast cavities. Cerro de Pasco Copper Corp. Bulletin 47.

Brass and bronze castings. Hammond Brass Works. Bulletin 48.

Reference on properties of lead. St. Joseph Lead Co. Bulletin 49.

6th edition of Revere Weights and Data Handbook. Revere Copper and Brass, Inc. Bulletin 296.

Catalog of brass, bronze and iron alloys. Cramp Brass and Iron Foundries Div., Baldwin Locomotive Works. Bulletin 50.

Dowmetal data book. Dow Chemical Co. Bulletin 51.

80-page Duronze Manual, well indexed for reference, presents data on high strength silicon bronzes. Bridgeport Brass Co. Bulletin 52.

Forgeable tin-free bearing metal. Mueller Brass Co. Bulletin 53.

Surface protection for magnesium. American Magnesium Corp. Bulletin 54.

Rare metals, alloys and ores. Foote Mineral Co. Bulletin 56.

Brazing Booklet. Westinghouse Elec. & Mfg. Co. Bulletin 57.

"The Story of Magnesium," illustrated booklet by the Permanente Metals Corp. Bulletin 261.

Two new Ampco Metal data sheets discuss forging Ampco to improve physical characteristics and use of Ampco for non-scratching feed fingers. Bulletin 314.

WELDING

"Sureweld" protected arc electrodes. Hollup Corp., division of National Cylinder Gas Co. Bulletin 58.

Welding Stainless. Page Steel & Wire Div., American Chain & Cable Co., Inc. Bulletin 59.

Chart explains how to select proper flux for every welding, brazing and soldering job. Krembs & Co. Bulletin 60.

Oxy-acetylene welding and cutting. Linde Air Products Co. Bulletin 62.

Flexarc A-C welders. Westinghouse Electric & Mfg. Co. Bulletin 64.

Data book facts on spot, seam and flash welding ferrous and non-ferrous metals and alloys. P. R. Mallory & Co., Inc. Bulletin 65.

Welding and brazing of aluminum, a new data book issued by Aluminum Co. of America. Bulletin 66.

Shield Arc electrodes. McKay Co. Bulletin 67.

New advances in arc welding equipment design. Harnischfeger Corp. Bulletin 68.

Nu-Braze No. 4, an improved silver brazing alloy. Sherman & Co. Bulletin 288.

New "200" welder is described by Allis-Chalmers in Bulletin 260.

New JR shape cutting machine is described by National Cylinder Gas Co. Bulletin 233.

New 12-page booklet tells how to fabricate fittings for welded piping by means of flame-cutting and welding. Air Reduction Co. Bulletin 234.

Use Handy Coupon on Page 577 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 577, 580, 582, 584, 586, 588 and 592.

In the reduction of metallic powders, INCONEL containers withstand over 2000° F. in complex corrosive atmospheres

The reducing of metallic powders . . . as a first step in the production of long-wearing, sintered-metal friction surfaces for brakes and clutches . . . imposes extremely severe conditions on the metal containers used in the process.

What these conditions are . . . and how they are met by Inconel containers . . . is shown by the experience of S. K. Wellman Co., pioneer in the field of powdered metallurgy.

When reducing metallic powders, the Wellman Co. uses Inconel cans, 20″ in diameter by 39″ high.

These cans are placed in an electric furnace where they are subjected to over 2000° F. for 72 hours.

Complete furnace assembly used in reducing metallic powders is shown at left. At right, heating cover is off to show Inconel container over oxide charge. Cans, 20″ x 39″, are of .062 and .125 Inconel sheet, arc welded.

Other destructive factors are present in addition to the high temperature.

The inside of the container is exposed to the action of carbon monoxide (reducing), carbon dioxide (oxidizing) and lead fumes (severely corrosive). The outside is exposed to an oxidizing atmosphere.

At first, steel cans were used; they lasted for only one 48-hour heat. Inconel cans, with Inconel covers, last for 50 to 75 heats —a total service of up to 5400 hours!

In addition to warping, the steel cans scaled, which affected the quality of the reduced metallic powders. Inconel's freedom from scaling avoids contamination.

An equally interesting performance by Inconel in the final phase of this Wellman operation . . . the "autodeous welding" of the sintered metal facing to a steel backing plate . . . will be described in a forthcoming issue.

* The details of this use of Inconel, a wrought nickel-chromium, heat-resistant alloy, are published in the belief that they will be of interest and value to engineers and designers working on similar problems, though the use of Inconel today is subject to conditions imposed by the War.

THE INTERNATIONAL NICKEL COMPANY, INC.
67 WALL STREET NEW YORK 5, N. Y.

★ ★ ★ ★ ★ **INCO NICKEL ALLOYS** ★ ★ ★ ★ ★

MONEL • "K" MONEL • "S" MONEL • "R" MONEL • "KR" MONEL • INCONEL • "Z" NICKEL • NICKEL

Sheet... Strip... Rod... Tubing... Wire... Castings

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Atomic-hydrogen arc welding, its application and use, is described by General Electric Co. in new Bulletin 241.

Welding alloys and metals on which they should be used are shown in helpful chart form by Eutectic Welding Alloys Co. Bulletin 242.

32-page catalog describes line of welding equipment offered by Victor Equipment Co. Bulletin 245.

Advantages and physical characteristics of "No-Wear", a hard-facing material. Callite Tungsten Corp. Bulletin 251.

Hard Facing Alloys. Wall-Colmonoy Corp. Bulletin 29.

New 500 lb. capacity welding positioner for light welding jobs is described by Ransome Machinery Co. Bulletin 313.

Two new hard-facing alloys furnished as welding rods for application by Oxy-Acetylene process are described by the Stoody Co. in Bulletin 325.

New line of welding positioners with dual capacity are described in new booklet by Harnischfeger Corp. Bulletin 350.

Vest pocket guide to correct welding practices is offered by Hobart Brothers Co. Bulletin 351.

Comparable arc welding electrodes for stainless are shown in chart issued by Alloy Rods Co. Bulletin 353.

Attractive, new booklet describes electric resistance welder for aluminum and its alloys. Sciaky Corp. Bulletin 358.

Helpful electrode color chart is offered by the Arcos Corp. Bulletin 374.

TESTING & INSPECTION

Bibliography of more than 700 papers dealing with the polarographic method of metal analysis and a booklet discussing this equipment is offered by E. H. Sargent & Co. Bulletin 338.

Various methods and specific applications of the measurement of case depth are described in illustrated pamphlet offered by Allen B. DuMont Laboratories, Inc. Bulletin 339.

Precision production tools such as surface plates, angle plates, straight edges, etc., are described in Catalog No. 42 issued by Acme Tool Co. Bulletin 340.

Metallurgical polishing equipment offered by Precision Scientific Corp. is described in illustrated booklet. Bulletin 359.

Catalog 600 issued by Precision Scientific Co. presents 112 pages on laboratory equipment and products. Bulletin 370.

SR-4 strain gage and illustrations of its many uses. Baldwin Southwark. Bulletin 70.

New book contains wealth of practical, usable information on industrial inspection by x-ray. Westinghouse Electric & Mfg. Co. Bulletin 71.

X-Ray Diffraction Unit. General Electric X-ray Corp. Bulletin 72.

Electric heaters and controls for industrial and laboratory. American Instrument Co. Bulletin 75.

Carbon-Meter for rapidly determining carbon at the furnace. E. Leitz, Inc. Bulletin 264.

Inspection of non-magnetic metals with the new Zyglo method. Magnaflux Corp. Bulletin 78.

Industrial radiography with radium. Canadian Radium & Uranium Corp. Bulletin 79.

Portable Brinell hardness tester and folding Brinell microscope. Andrew King. Bulletin 85.

Gage blocks, comparators, projectors. George Scherr Co. Bulletin 83.

Universal testing machines and typical uses. Riehle Testing Machine Div., American Machine and Metals, Inc. Bulletin 86.

Surface Analyzer. Brush Development Company. Bulletin 88.

Dillon tensile tester and the Dillon dynamometer. W. C. Dillon & Co. Bulletin 91.

Optical Aids. Bausch & Lomb Optical Co. Bulletin 94.

Coleman universal spectrophotometer. Wilkens-Anderson Co. Bulletin 95.

Metallographic polishing powder. Conrad Wolff. Bulletin 96.

Metallurgical Equipment. Adolph I. Buehler. Bulletin 97.

Hardness testing equipment. Wilson Mechanical Instrument Co., Inc. Bulletin 98.

Identometer for rapid identification of steel. Dravo Corp. Bulletin 267.

Eberbach micro hardness tester is illustrated and described in new booklet by Eberbach & Son Co. Bulletin 269.

Moisture determinations of a wide range of materials with new Moisture Teller instrument are described in new leaflet by Harry W. Dietert Co. Bulletin 299.

New flexible film holder for industrial radiography is illustrated and described in leaflet by Picker X-Ray Corp. Bulletin 300.

Stresscoat, a method of analyzing distribution, direction and value of local strains in any structure by means of formation of characteristic crack patterns in a brittle coating applied to its structure, is described in leaflets issued by Magnaflux Corp. Bulletin 301.

Attractive, illustrated booklet describes Clark Instrument's precision hardness tester. Bulletin 318.

"Radiography of Materials" is title of new 96-page book on industrial radiography. Eastman Kodak Co. Bulletin 331.

TEMPERATURE CONTROL

New catalog covers ATC Type 3 electrical control motors for regulating temperature, pressure, flow, etc. in numerous installations in the heat treating field and elsewhere. Automatic Temperature Control Co. Bulletin 349.

New 29-page catalog — Micromax Electric Control — has just been issued by Leeds & Northrup Co. Bulletin 76.

Potentiometer temperature indicators. Foxboro Co. Bulletin 82.

Pyrometer control of high speed salt baths is described in new booklet by Brown Instrument Co. Bulletin 324.

40-page booklet contains useful technical information on thermometry and thermometers. Bristol Co. Bulletin 321.

Micro-Optical Pyrometers. Pyrometer Instrument Co. Bulletin 89.

New file folder service bulletin on Weaver Furnace Atmosphere Indicator. Claud S. Gordon Co. Bulletin 332.

New condensed catalog gives prices and descriptions of instruments offered by Wheelco Instruments Co. Bulletin 268.

Industrial thermocouples. Arklay S. Richards Co. Bulletin 93.

Pyrometer Controller. Illinois Testing Laboratories, Inc. Bulletin 84.

HEATING • HEAT TREATMENT

36-page catalog illustrates Kold-Hold line of thermal, sub-zero and stratosphere processing and testing machines. Kold-Hold Mfg. Co. Bulletin 99.

Homo method for nitriding is described and illustrated in new 19-page catalog by Leeds & Northrup. Bulletin 100.

Lithco, the chemically-neutral heat treating process, and Lithcarb, the process for fast, bright gas-carburizing. Lithium Corp. Bulletin 101.

Internally heated salt bath furnaces and pots. Upton Electric Furnace Div. Bulletin 102.

Induction heating. Induction Heating Corp. Bulletin 103.

Easy-selection charts on gas-burning equipment. National Machine Works. Bulletin 105.

8-page pictorial bulletin describes the heat treating service of Continental Industrial Engineers, Inc. Bulletin 107.

Hagan rotary forging furnaces are described in bulletin by George J. Hagan Co. Bulletin 108.

Use Handy Coupon on Page 577 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 577, 578, 582, 584, 586, 588 and 592.

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Centrifugal blowers and exhausters. Roots Connersville Blower Corp. Bulletin 270.

Furnaces for heat treatment of aluminum, magnesium and their alloys. Lindberg Engineering Co. Bulletin 271.

Electric Furnaces. Ajax Electrothermic Corp. Bulletin 106.

Rotary Hearth Furnaces. Lee Wilson Sales Corp. Bulletin 290.

Gas, oil and electric heat treating and carburizing furnaces. Holcroft & Co. Bulletin 114.

Industrial furnaces, equipment for bright annealing stainless steels and ammonia dissociation equipment. Drever Co. Bulletin 115.

Industrial ovens, rod bakers, welding rod ovens, furnaces. Carl-May[er] Corp. Bulletin 116.

Full muffle and other heat treatin[g] furnaces described in catalog b[y] Charles A. Hones, Inc. Bulletin 11[7]

56-page vest pocket data book o[n] heat treating practices and proc[e]dures. Chicago Flexible Shaft C[o.] Bulletin 118.

Non-metallic Electric Heating El[e]ments. Globar Div., Carborundu[m] Co. Bulletin 119.

24-page catalog describes gas, o[il] and electric Holden heat treating p[ot] furnaces, and baths. A. F. Holden C[o.] Bulletin 120.

Modern electric furnaces for he[at] treating. Harold E. Trent Co. in ne[w] Bulletin 121.

Control of temperatures of quenc[h]ing baths. Niagara Blower Co. Bu[l]letin 122.

Molten Salt Baths. E. I. DuPo[nt] de Nemours & Co., Inc., Electrochem[]icals Department. Bulletin 123.

Tocco hardening, brazing, anneal[]ing and heating machines. Ohi[o] Crankshaft Co. Bulletin 124.

Drycolene. General Electric fu[r]nace atmosphere. Bulletin 131.

Dual-Action quenching oil. G[]Oil Co. Bulletin 132.

Handling cylinder anhydrous am[]monia for metal treaters. Armou[r] Ammonia Works. Bulletin 128.

Industrial Furnaces. W. S. Rock[]well Co. Bulletin 133.

Certain Curtain Furnaces. C. I. Hayes, Inc. Bulletin 134.

Air-Oil Ratiotrol for proportionin[g] flow of fuel oil and air to oil burners North American Mfg. Co. Bulleti[n] 135.

Blue Print for Industry, new hand[]book presenting oven engineerin[g] information. Industrial Oven Eng[i]neering Co. Bulletin 136.

Two new bulletins on vertical car[]burizers and on carbonia finish American Gas Furnace Co. Bulle[]tin 139.

Van Norman induction heatin[g] units. Van Norman Machine Tool Co. Bulletin 144.

Gas-air premix machine. Eclips[e] Fuel Engineering Co. Bulletin 138.

Low temperature equipment fo[r] aging, shrinking, etc. Deepfreez[e] Div., Motor Products Corp. Bulletin 140.

Controlled atmosphere furnace[s] Delaware Tool Steel Corp. Bulleti[n] 141.

Furnaces. Tate-Jones Co. Bulletin 142.

Industrial Carburetors. C. M. Kemp Mfg. Co. Bulletin 143.

High and low temperature direc[t] fired furnaces. R-S Products Corp. Bulletin 146.

Heat treating, brazing and melt[]ing of ferrous and non-ferrous met[]als. Lepel High Frequency Labora[]tories, Inc. Bulletin 147.

Use Handy Coupon on Page 577 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 577, 578, 580, 584, 586, 588 and 592.

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Vertical Furnace. Sentry Co. Bulletin 148.

Conveyor Furnaces. Electric Furnace Co. Bulletin 149.

New Electric Furnace. American Electric Furnace Co. Bulletin 150.

Salt bath material for use in Martempering process. E. F. Houghton & Co. Bulletin 151.

Electric Furnaces for laboratory and production heat treatment. Hoskins Mfg. Co. Bulletin 152.

Furnace Experience. Flinn & Dreffein Co. Bulletin 153.

Flame-type mouth and taper annealing machine for steel cartridge cases. Morrison Engineering Corp. Bulletin 154.

Dehumidifier. Pittsburgh Lectrodryer Corp. Bulletin 155.

No-Carb, a liquid paint for prevention of carburization or decarburization. Park Chemical Co. Bulletin 156.

16-page engineering and data booklet on proportioning oil burners. Hauck Mfg. Co. Bulletin 160.

High Temperature Fans. Michiana Products Corp. Bulletin 158.

Pictorial bulletin describes furnaces for heat treating, normalizing, annealing, forging. Vulcan Corp. Bulletin 161.

Protective combusted atmospheres in Hevi Duty Electric Co. furnaces are discussed in 12-page Bulletin 316.

Turbo-Compressor data book shows how to calculate compressed air systems for a dozen different applications. Spencer Turbine Co. Bulletin 329.

Catalog of heat treating materials. Heatbath Corp. Bulletin 322.

Besides high-speed steel hardening, Ajax Electric Co. Bulletins 110 and 107-A cover the equally impressive Ajax performance in carburizing, neutral hardening, etc. Bulletin 342.

Surface Combustion hardening furnaces for many production requirements are described in new leaflet. Bulletin 352.

Photographs and drawings are used to describe car type quick-anneal oven by Whiting Corp. Bulletin 355.

Laboratory and tool room furnace Mahr Mfg. Co. in new Bulletin 327.

Standardized sizes of semi-muffle and pot-type furnaces are described and pictured in new leaflet by Dempsey Industrial Furnace Corp. Bulletin 354.

Use of pulverized coal in the metallurgical industries, equipment and designs, are described by Amsler Morton Co. in Bulletin 361.

Furnaces for heat treating tools, dies and parts are described in new leaflet by Despatch Oven Co. Bulletin 362.

Rapid oil coolers and heat transfer equipment are described in new catalog issued by Bell & Gossett Co. Bulletin 365.

New book "Hardness" describes and evaluates hardness research of noted pioneers, methods of testing and testing instruments. Nitralloy Corp. Bulletin 366.

New booklet describes uniform case hardening up to .150" with controlled carburizing baths. American Cyanamid & Chemical Corp. Bulletin 372.

Heat treating atmospheres are discussed from A to Z in new booklet by Westinghouse Electric & Mfg. Co. Bulletin 373.

Use Handy Coupon on Page 577 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 577, 578, 580, 582, 586, 588 and 592.

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

REFRACTORIES & INSULATION

Insulating firebrick. Babcock & Wilcox Co. Bulletin 162.

Cromox, new protective refractory coating material for prolonging life of firebrick, insulating firebrick, and castable refractories. Federal Refractories Corp. Bulletin 163.

Heavy Duty Refractories. Norton Co. Bulletin 164.

Super Refractories catalog. Carborundum Co. Bulletin 165.

Interesting data sheets on Therm-O-Flake insulating bricks and coatings. Illinois Clay Products Co. Bulletin 298.

Conductivity and heat transfer charts. Johns-Manville. Bulletin 167.

Ramix bottom for basic open hearth furnaces. Basic Refractories, Inc. Bulletin 168.

Brickseal refractory coating. Brickseal Refractory Co. Bulletin 169.

D-E insulating materials and their application are described in new data booklet by Armstrong Cork Co. Bulletin 208.

Corhart Electrocast Refractories for the melting and refining of metals are described by Corhart Refractories Co. Bulletin 209.

Zircon refractories in aluminum open hearth furnaces are discussed in new leaflet by Chas. Taylor Sons Co. Bulletin 347.

H-W magnamix, a Washington magnesite ramming mixture for open hearth and electric steel furnaces, is described in new leaflet by Harbison-Walker Refractories Co. Bulletin 371.

FINISHING • PLATING • CLEANING

Roto-Finish equipment for deburring, buffing, polishing and coloring. Sturgis Products Co. Bulletin 170.

A protective, deep black finish to steel. Heatbath Corp. Bulletin 171.

Alvey Ferguson Co. shows how various product washing problems were solved. Bulletin 172.

Four new booklets describe blackening processes for metals. Enthone Co. Bulletin 276.

Pickling. Wm. M. Parkin Co. Bu-
letin 174.

Motor-Generators for electropl-
ing and other electrolytic process-
Columbia Electric Mfg. Co. Bulle-
173.

Detrex metal cleaning machin-
metal cleaning chemicals and pro-
essing equipment. Detrex Corpor-
tion. Bulletin 175.

Electrochemical Descaling. Bu-
lard-Dunn Process Div., Bullard C-
Bulletin 212.

Airless Rotoblast. Pangborn Cor-
Bulletin 176.

Rust inhibiting wax coatings f-
protection of metal. S. C. Johnson
Son, Inc. Bulletin 180.

Cadmium Plating. E. I. duPo-
deNemours & Co., Inc. Bulletin 17-

Tumbling and cleaning. Glo-
Stamping and Machine Co. Bulle-
179.

Catalog on finishing and cleanin-
Frederick Gumm Chemical Co., In-
Bulletin 292.

Resilon corrosion-resistant ta-
linings and applications are d-
scribed in 8-page leaflet by Unit-
States Stoneware Co. Bulletin 29-

"Indium and Indium Plating". I-
dium Corp. of America. Bulletin 1-

Service report describes use o-
Oakite machining, drawing, degre-
ing and descaling materials. Oak-
Products, Inc. Bulletin 210.

Jetal process and its characteri-
tics as a protective coating. Alro-
Chemical Co. Bulletin 213.

Catalog section on new sheet Kor-
seal linings for tanks of welded ste-
wood or concrete has been issued b-
the B. F. Goodrich Co. Bulletin 11-

Lead plating is discussed in ne-
booklet issued by Harshaw Chemic-
Co. Bulletin 109.

Catalog shows typical cleaning an-
finishing machines engineered an-
built by Howard Engineering & M-
Co. Bulletin 110.

Four types of solvent degrease-
and cleaners are described in ne-
leaflet by Technical Processes Di-
Colonial Alloys Co. Bulletin 230.

Discussion of anodizing, chrom-
tizing and phosphatizing in illu-
trated 60-page book has been issue-
by Turco Products, Inc. Bulletin 24-

Revised edition of "The Americ-
Line", 20-page reference catalog o-
entire line of products manufactur-
by American Foundry Equipment C-
has just been released. Bulletin 34-

112-page manual describes Chem-
icals by Glyco. Glyco Products C-
Bulletin 346.

Cleaning castings and forgings a-
low cost by tumbling is described i-
leaflet by Whiting Corp. Bulletin 35-

Illustrated booklet describes bla-
cleaning equipment offered b-
Ruemelin Mfg. Co. Bulletin 368.

Use Handy Coupon on Page 577 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 577, 578, 580, 582, 584, 588 and 592.

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

MELTING • CASTING • MILL OPERATIONS

Cradle furnace which produces a homogeneous gray iron of uniform chemical analysis, uniform temperature and controlled carbon content is described by Whiting Corp. Bulletin 357.

Interesting and helpful information available on the use of alloy pots for heating operation by the Swedish Crucible Steel Co. Bulletin 137.

Crucibles for brass, copper, aluminum and magnesium industries. Electro Refractories and Alloys Corp. Bulletin 183.

Ingot Production. Gathmann Engineering Co. Bulletin 185.

Manganese-Titanium Steels. Titanium Alloy Mfg. Co. Bulletin 184.

"Electromet Products and Service". Electro Metallurgical Co. Bulletin 186.

Chrom-X for steel mill and foundry. Chromium Mining & Smelting Co. Bulletin 187.

Lectromelt Furnaces. Pittsburgh Lectromelt Furnace Corp. Bulletin 188.

Electric Furnaces. Detroit Electric Furnace Div., Kuhlman Electric Co. Bulletin 189.

Stroman crucible melting furnaces for aluminum and magnesium are described in leaflet by Stroman Furnace & Engineering Co. Bulletin 277.

Operating Features, capacities, charging methods of the Heroult electric furnace. American Bridge Co. Bulletin 215.

Chart for the correction of brasses for zinc loss should interest foundrymen. Foundry Services, Inc. Bulletin 217.

Coke oven plant construction and development in 1942 is described and illustrated in 12-page pamphlet by the Koppers Co. Bulletin 232.

"Fisher Magnesium Scrapbook". Fisher Furnace Co. Bulletin 281.

Attractive booklet describes growth, facilities and offers valuable alloy hints. Niagara Falls Smelting & Refining Corp. Bulletin 246.

Vertical centrifugal casting machine for production of ferrous and nonferrous castings is described by Centrifugal Casting Machine Co. in Bulletin 315.

Interesting, descriptive leaflet on metal reclaiming mill offered by Dreisbach Engineering Corp. Bulletin 284.

Use Handy Coupon on Page 577 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 577, 578, 580, 582, 584, 586 and 592.

WHAT'S NEW
IN MANUFACTURERS' LITERATURE

ENGINEERING • APPLICATIONS • PARTS

Catalog gives complete specification data on Bunting bearings and bars. Bunting Brass & Bronze Co. Bulletin 343.

Heat treating fixtures for pit-type furnaces are shown in new booklet by Driver-Harris Co. Bulletin 363.

Pressed steel pots are described by Bell & Gossett Co. in new Bulletin 364.

54-page booklet, "File 41—Engineering Data Sheets", gives complete facts on Ampco Metal's physical properties and service record. Bulletin 368.

New information sheets on tapered and formed tubes have just been issued by Summerill Tubing Co. Bulletin 369.

Chace manganese alloy No. 772 in sheets, strips, rod and special shapes described by W. M. Chace Co. Bulletin 190.

Duraspun Centrifugal Castings. Duraloy Co. Bulletin 194.

Electrical, corrosion and heat resisting alloys in rod, wire, ribbon and strip forms. Wilbur B. Driver Co. Bulletin 192.

Carburizing Boxes. Pressed Steel Co. Bulletin 193.

Meehanite Castings. Meehanite Research Institute. Bulletin 196.

X-Ray Inspected Castings. Electro Alloys Co. Bulletin 197.

Steel Castings. Chicago Steel Foundry Co. Bulletin 199.

Heat Resisting Alloys. General Alloys Co. Bulletin 200.

Pipes and Tubes. Michigan Steel Casting Co. Bulletin 201.

Bimetals and Electrical Contacts. H. A. Wilson Company. Bulletin 202.

Cr-Ni-Mo Steels. A. Finkl & Sons Co. Bulletin 203.

Industrial baskets, crates, trays and fixtures. Rolock, Inc. Bulletin 204.

Cooper standard alloys. Cooper Alloy Foundry Co. Bulletin 206.

Alloy Castings. Ohio Steel Foundry Co. Bulletin 207.

Flanges and other drop forgings. Ladish Drop Forge Co. Bulletin 221.

Lead-base metals. Magnolia Metal Co. Bulletin 226.

Many applications and savings through use of drop forgings are shown in Drop Forging Topics, issued by Drop Forging Assn. Bulletin 240.

24-page catalog is guide to properties and use of Monsanto plastics. Monsanto Chemical Co. Bulletin 319.

Details of new Chemicast process for small brass parts will be supplied by Chemicast Div., Whip-Mix Corp. Bulletin 330.

Use Handy Coupon on Page 577 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 577, 578, 580, 582, 584, 586 and 588.

New Products and Services

etallographic Equipment

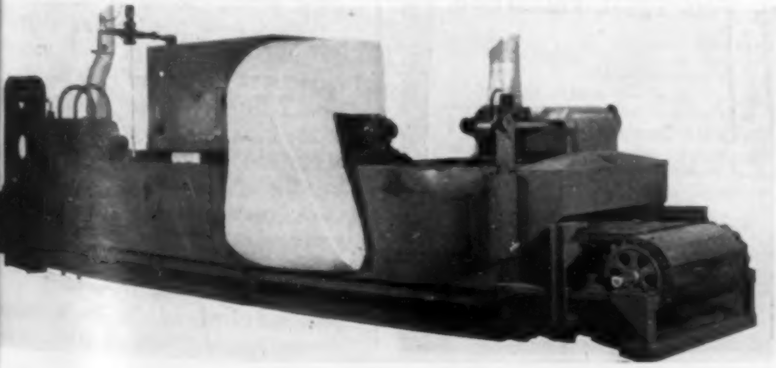
Precision Scientific Co., 1736 . Springfield Ave., Chicago, will hibit working models at the tional Metal Congress and War nference Displays of "Precision-rrett" metallographic equipment. acy C. Jarrett, chief metallurgist American Hammered Piston Ring vision of Koppers Co., is retained consulting metallurgist, and the e will include apparatus orig-ally developed by Dr. Jarrett and rmerly marketed by himself.

s Cooler Permits Improved nnealing

Annealing, drawing, tempering d stress relieving operations are id to be improved with the gas oler offered by Brown Fintube , Elyria, O. Hot gases are with-awn from a furnace operating on heating cycle at temperatures nging from 1200 to 1600° F. and ssed through the cooler which duces their temperature to any sired level. Cooled gases are en passed into another furnace, rmitting the work in this furnace be annealed, drawn or stress lieved, at the exact temperature produce the physical qualities sired — in a non-oxidizing atmos-here. These coolers consist of a nk of resistance-welded fintubes, elded to headers at each end and ounted in an insulated steel hous-g or shell.

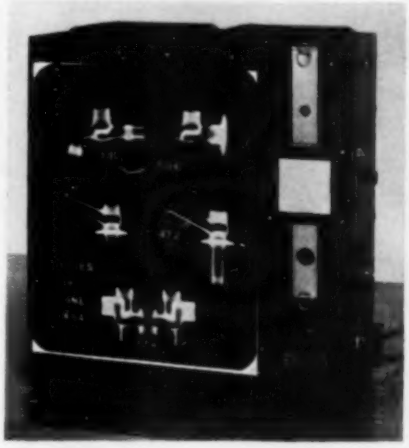
ust Preventive

A new hard-drying rust pre-ntive providing a glossy, dry, thin m is announced by E. F. Houghton Co., Philadelphia. This product, own as Rust Veto 110A, is a light, ber-colored liquid applied by ush or spray. It dries in 25 to min.



X-Ray Illuminator

High intensity illuminator for examination of industrial X-ray films is announced by the Kelley-Koett Mfg. Co., 212 W. 4th St., Covington, Ky. Said to provide four times more illumination than heretofore available, it reveals film detail formerly missed, and enables



the user to examine films of greater density with resultant improvement in radiographic contrast. View box is equipped with a Variac control which affords a stepless increase in intensity by varying voltage from 0 to 110 volts.

Stress-Relieving

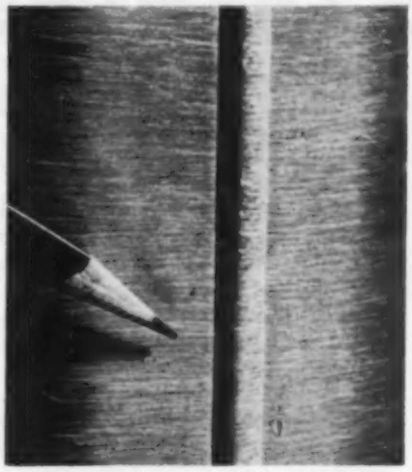
Designed for stress-relieving of armor-piercing shot in an Ohio ordnance plant, this continuous draw furnace is now one of a series of units constructed in various sizes, temperature ranges and capacities for general industry, by the Industrial Oven Engineering Co., 11621 Detroit Ave., Cleveland. Furnace is built for temperature ranges up to 900° F. and maintains this uniformly to ± 3° throughout the length, width and height of the work zone. Economy of operation results from efficiently designed air heater, duct and recirculation system. Unit illustrated is gas fired, but equipment for oil or electric heat is available.

Furnace Temperature Control

"Furnatron" control system to keep furnace temperature variations to a minimum is offered by Westinghouse Electric & Mfg. Co., East Pittsburgh. System combines a suitable thermocouple type of temperature controller with automatic electronic control of a saturable reactor connected in the supply line of the furnace elements, thus automatically controlling the power input.

Helium-Shielded Arc Welding

Development of both manual and automatic arc-welding equipment specifically designed for the welding of magnesium, magnesium alloys, aluminum and other high-strength light alloys under a protec-



tive shield of helium gas, has been announced by C. I. MacGuffie, manager of General Electric's electric welding division. Such equipment should greatly extend the use in war production of the lighter metals whose welding demands precise control of concentrated heat and protection of the molten metal from oxygen in the air. Filler metal is fed from one side, and arc and protective stream of helium comes down from above. Length of arc is held automatically by electronic control; stopping, starting and other movements by push-button control. Illustration shows a butt joint in ⅛-in. magnesium plate welded at the rate of 24 in. per min.

(More on page 608)

New Products

Spectrographic Analysis

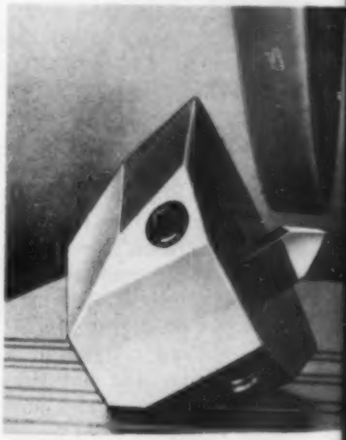
Multisource electrical unit for spectrographic analysis is announced by the Harry W. Dietert Co., Detroit, and their associate firm, the Applied Research Laboratories of Glendale, Calif. It not only combines the functions of the conventional D.C. arc, A.C. arc, and high voltage condensed spark units, but it goes far beyond any of them in providing precisely controlled excitation, suitable for all types of analytical work. By virtue of the wide variation in excitation conditions obtainable, either arc-like or spark-like spectra, with all variations in between, may be had.

Bonding Method

Reanite Bonding Process for bonding metal to metal, or to other materials, with a bond often stronger than the materials themselves, and stronger than riveted or spot welded joints, has been a[n]nounced by the U. S. Stonewa[re] Co., Akron, O. Surfaces to [be] joined are brushed, sprayed [or] dipped with Reanite. After dryi[ng] mild heat and pressure are appli[ed]. Joint is unaffected by fresh or s[alt] water, is non-corrosive to meta[ls,] possesses excellent corrosion resis[t]ance in itself, and high dielectr[ic] strength. While the bond develo[ps] its maximum strength at room te[m]peratures, its strength over a te[m]perature range of from −40° F. [to] as high as 300° F. is substantiall[y] stronger than bonds obtained [by] conventional processes.

Thread-Tool Grinding Fixture

Simple and unique thread-to[ol] grinding fixture for grinding bo[th] 60° and 29° tool bits with extre[me] precision is announced by Robe[rt] H. Clark Co., Los Angeles. Fixtu[re] has no graduated scales or movin[g] parts; the machinist merely slide[s]



the bit into the holder, tightens [the] setscrew and places the fixture [on] the grinder work table, resting [on] the face which gives the desire[d] thread angle. This automaticall[y] holds the bit securely and precisel[y] at the desired angle to the grindi[ng] wheel. Available in two sizes, eac[h] of which takes all tool bits withi[n] a ⅛ to ⅝-in. range.

New Hard-Facing Alloys

Two new hard-facing alloys [of] cobalt, chromium and tungst[en] have been announced by the Stood[y] Co., Whittier, Calif. Both are fur[]nished as welding rods for oxy[]acetylene weld-on. Stoody 1, th[e] harder of the two alloys, provide[s] high resistance to abrasion, co[r]rosion and heat. Stoody 6 is muc[h] more ductile and provides muc[h] greater resistance to impact. Both are supplied in ⅛ to ⅝-in. ro[d] diameters, in 14-in. lengths.

P&H

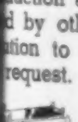
AMERICA'S ONLY MANUFACTURER PROVIDING A COMPLETE WELDING SERVICE

re, under one roof, the builder of welding ipment is also one of the world's largest rs. Pioneers in production welding, P&H always led the way with new methods techniques as well as in designing for welded fabrication.

The new P&H Production Welding Control System will be demonstrated at the Metal Show, Room 813, Palmer House, Chicago, Oct. 18-22, 1943.

PRODUCTION CONTROL SYSTEMS

The P&H system of Production Welding Control can readily be applied to any of the basic methods of compensation to accurate control of (1) costs, (2) procedures, (3) duction and (4) quality. Originated by P&H and d by other large companies, it is the practical tion to production welding control. Literature request.

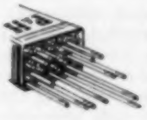


D.C. ARC WELDERS

All with single control and the new "Visi-matic" calibration plate. All P&H arc welders are rated on the WSR (Welding Service Range) basis, which s you the exact amount of usable welding current. n minimum to maximum, for each machine. acities up to 600 amperes.

A.C. ARC WELDERS

A new series of industrial machines (for both intermittent and heavy duty service) with a wide range of capacities. All models provide the continuous, centrated arc which is so easy to control. The plete line includes models from 20 to 1200-ampere pacity based on WSR ratings.



WELDING ELECTRODES

Produced under rigid quality control in one of America's most modern electrode plants. All sizes and types for maintenance and repair work such as for hard surfacing, resistance to impact, wear, and abrasion. Also for welding stainless, 4-6% chrome steels, armor plates, etc., as well as all types of mild steel electrodes.

WELDING POSITIONERS

A complete line of dual capacity welding positioners up to 24,000 lbs. capacity; power operated for handling various sizes and types of welded structures. New designs provide the utmost simplicity of operation to facilitate production welding. Literature on request.

ELECTRIC HOISTS

Used in welderies everywhere for the handling of steel, sub-assemblies, etc. All capacities up to 15 tons are made in three series of hoists which provide a variety of mountings to suit every need for lifting, lowering, or horizontal travel. Literature on request.

OVERHEAD CRANES

P&H is America's largest builder of overhead cranes. Whether for heavy duty or for intermittent service, P&H builds a size and type exactly suited for each requirement. You can count on P&H's honest delivery dates.

General Offices:

4549 West National Avenue, Milwaukee 14, Wisconsin

HARNISCHFEGER CORPORATION

ARC WELDERS • EXCAVATORS • ELECTRIC CRANES P&H MOTORS • HOISTS • WELDING ELECTRODES

New Products

Heat Exchanger

For maintaining constant temperatures in industrial liquids, with automatic control, announced by Niagara Blower Co., 6 E. 45th St., New York 17, N. Y. It is an evaporative type of liquid cooling unit using a water spray and fans to draw air over coils containing the liquid whose temperature is to be controlled, and is accomplished with the Aero Heat Exchanger by using either a steam coil or injector or an electric heating unit to heat the spray water.

Expansion

Cooper Alloy Foundry Co., Hillside, N. J., has completed a new plant to make centrifugally-cast alloy castings for aircraft and other services.

New Welding Positioners

Newly-designed line of welding positioners by Harnischfeger Corp., Milwaukee 14, Wis., has great[er] adaptability and ease of operatio[n] thus giving more actual arc time f[or] production lines. One feature [is] the dual capacity rating of eac[h] model. For example, the WP-6 [in] the 6000-lb. class, handles loads u[p] to 6000 lb. maximum and also has [a] secondary capacity of 9000 l[b.] Standard models are being made [in] dual capacities up to 24,000 lb., a[nd] all models are supplied for A.C. [or] D.C. current.

New Chemical Stoneware

A new chemical stoneware th[at] withstands violent thermal shock has been announced by U. S. Stoneware Co., Akron, O. Known [as] "Ceratherm 500", it is said to [be] the first low-porosity chemic[al] stoneware that can be heated [by] direct steam or hot gases, and th[at]

can be cooled quickly. It is [in] production on such items as tan[ks,] crocks, boiling kettles, mixing ke[t]tles, cooling and condensing coi[ls,] evaporating dishes, pumps, sin[ks] and pipe. Materials used are [n]on-critical, and priorities are n[ot] necessarily a pre-requisite to obta[in] "Ceratherm 500".

Oil Re-Conditioner

Developed by the Sparkler M[fg.] Co., Mundelein, Ill., this is a co[m]plete oil treating, filtering and r[e]conditioning machine, especial[ly] designed for reconditioning cuttin[g,] grinding, and honing oils th[at] should be heated and sterilized b[e]fore filtering. It is claimed th[at] sulphonated oils, lard oils, lubrica[t]ing oils and many others can [be] restored to their original efficienc[y]

Editorial

Critical Points

By The Editor

Edge on Bombers

THE ENGINEER, the old reliable British weekly, recently printed editorially an analysis of enemy aircraft losses from which the following comfortable statistics are taken, admittedly in round numbers:

Average present daily loss to Axis on eastern front	50
Average present daily loss in Mediterranean area	50
Estimated daily loss on ground and flying accidents	50
Total loss to Axis:	150 per day
Production rate of Axis in Europe in 1942, per day	100
Loss in daily production rate by bombed-out factories	30
Present daily production	70 per day
Net wastage of Axis aircraft	**80 per day**
American production, alone, of combat aircraft, per day	200 plus

(Buy more bonds, and build more bombers!)

FOUND Robert Mitchell Co.'s model foundry in Montreal all converted from casting hard industrial jobs in alloy iron and bronze to harder aircraft jobs in magnesium and aluminum, and enforcing all special precautions shown in April 1942 in *Metal Progress'* notable pictures of Dow's magnesium foundry. Radiography has here become the prime method of quality control; when gross defects are suspected or found on films, the entire heat is examined and culled under a fluoroscope, thus reserving the films for pieces apparently sound. The device is simple; a hand-operated belt carries the castings into the lead-lined chamber under a 220,000-volt Westinghouse tube, the castings are manipulated by metal fingers passing through the walls, and the image safely viewed through a lead glass window and mirror combination .... MARC CHICOINE, assistant metallurgist, emphasized the value of corrugated iron or bronze chills for avoiding porosity in the castings; prior to placing in the molds they are cleaned and roughened by sand blasting. Hundreds of special shapes are stored against use in individual bins. Also impressed by the great number of neatly uniformed girls in the core and finishing departments; about as much time is given to slicking up the baked cores as to the finished castings.

X-ray control of magnesium foundry

EVEN LARGER numbers of women (although in costumes of a different color) operate the press lines in Mitchell's artillery cartridge plant, recently erected. Each press is served by a team; one girl dips the disk or cup in slushing compound and places it in the feeder slide, and the other operates the feeder lever and trips the press — to a steady rhythm, 30 a minute, and the long straight line of powerful presses all surging into action makes one huge swinging hammer of Thor beating endlessly .... Two operations — indenting the bottom of the half-drawn case, and heading the base into its final shape — are performed on presses with three-position tools, one for loading, one for pressing, one for ejecting; position No. 1 was fed automatically until several tools were broken by improperly seated work .... Discussed with ALAN JOHNSON, engineer of the cartridge case division, the problem of an entirely automatic shell plant. It seems that mechanical feeders are far from faultless, and mis-adjustments would slow down the operation of a press line considerably unless more positive mechanisms could be devised. One great gain has resulted from a revision in the pickling machinery, substituting for the dip tank a con-

A million rounds per month

veyor line carrying the cartridge past a series of acid and wash water sprays, internal and external. (Oh, for a bright anneal! — or do we need a little roughness to hold the drawing lubricants?) Gaging machinery ought to help too, for long lines of dextrous girls now measure each cartridge ten ways, much of this work being repeated a few minutes later by government inspectors . . . . Inspection department insists on music while you work, and methinks that almost any tune from Palestrina to Pasternak would relieve the day-long monotony of go, no-go, go, no-go, go, no-go. Physical inspection is confined to an hourly selection of a single case whose Vickers hardness is measured end to end (with no interior anvil or plug except at the mouth). No definite specification exists, but the curve always falls within a narrow band. Seemingly the various anneals of the entire cup, of the skirt and finally of the mouth are balanced against the amount of cold work in each of the dies so that disks originally of proper composition and grain size end up with correct physicals for safe firing.

GLIMPSED an entirely new viewpoint of toolmaking at the brand new Westmount Tool Works in Montreal, making tools for an ammunition program turning out more in a single month than Canada produced during the entire first world war. For such production it was apparent that many thousands of punches, dies and gages must be made daily. From the established peacetime ammunition works of Canadian Industries Limited came a few toolmakers who were skilled artisans, even artists, and the problem was to multiply their skill a hundred-fold. George Scott, past chairman of Montreal Chapter ⊕, retired after making telephone equipment for 40 years in the tooling department of Northern Electric, was "dug out" and shared in this job, ably aided by Herbert Odd, one time in the gage division of the National Physical Laboratory in England. Neither of these men was an ammunition maker, so they looked upon a cartridge drawing die not as a craftsman's product but as a metal part of accurate shape and high hardness. If they were correct in this viewpoint, such a die could be produced interchangeably in quantity like a roller bearing race or any other precise machine part. . . . Once that idea was adopted it was necessary to make accurate drawings of each of the 229 tools required to make a round of 0.303-caliber ammunition, and to decide what dimensional variations could be tolerated — narrow enough so that the manufactured part would function correctly, yet broad enough so the tool could be made on modern screw machines, turret lathes and grinders. While the shape of the cartridge or bullet jacket in its various stages was copied from the shapes acquired from experience, the actual tools were frequently redesigned to remove useless excrescences and to adapt them to improved arsenal

Tools made in mass production

A Few 2000-Hp. Engines, Made by Buick, for Consolidated B-24 ("Liberator") Bombers

machinery....Next — in view of the certainty that these tools must be made by workmen who were not even machinists, let alone toolmakers — a series of operational drawings was made for each tool, showing in detail every step in its metamorphosis from the hot rolled steel bar. (These documents are mounted at the various machine tools to show the operator exactly what he is to do.) That staggering designing and drafting job under way, not only for 0.303 ammunition but for four other calibers, machine tools were assembled in real production lines, one for punches, one for heading dies, one for forming dies, one for drawing dies, and another for miscellaneous tools. (Production lines even for gages are now being set up.)....Generally speaking, the steps are about the same in each tool line: *(a)* Prepare the stock, *(b)* machine, usually in screw machines, *(c)* finish in turret lathes or "second operation" machines, *(d)* quench from controlled atmosphere, *(e)* machine grind, *(f)* finish by lapping, hand polishing and buffing. Individual inspection is instituted after each step except the first, often requiring ingenious gages and many optical comparators, and here is where production control must be ever vigilant, to search out and correct the cause *immediately* any undue proportion of rejects appears....All this work has been completed in about two years (actual production of certain parts started within a month). There are practically no machinists working on production operations — a high percentage of the workmen are in fact young women who had never been closer to machinery than to a Singer or a Hoover, and who graduate to an automatic after a brief course of intensive training for the particular job....

Wear and breakage steadily decreasing

As to the quality of Westmount's tools, this was amply proven during a trip through the Verdun ammunition plant, when D. Cameron, plant metallurgist, said that the consumption of tools was steadily dropping. This, also, for precise ammunition, much of it used in aircraft where the scatter of hits at 600 yd. must be very small — technically expressed as an "8-in. figure of merit". Other evidence of tool quality comes from the recent change from cupro-nickel bullet jackets to steel clad with gilding metal; production was easily maintained with no changes other than to correct for larger spring-back .... Steels used at Westmount Tool Works must be machinable in automatics; they are mostly plain high carbon toolsteels for punches and 1.25% tungsten toolsteels for wear-resisting dies — thus also conserving strategic alloying elements. One unsolved problem is warpage of long punches during heat treating. Many quenching schemes have been tried; current is Tocco hardening by lowering vertically through a short inductor, rotating the punch so variations in the quenching spray are equalized.

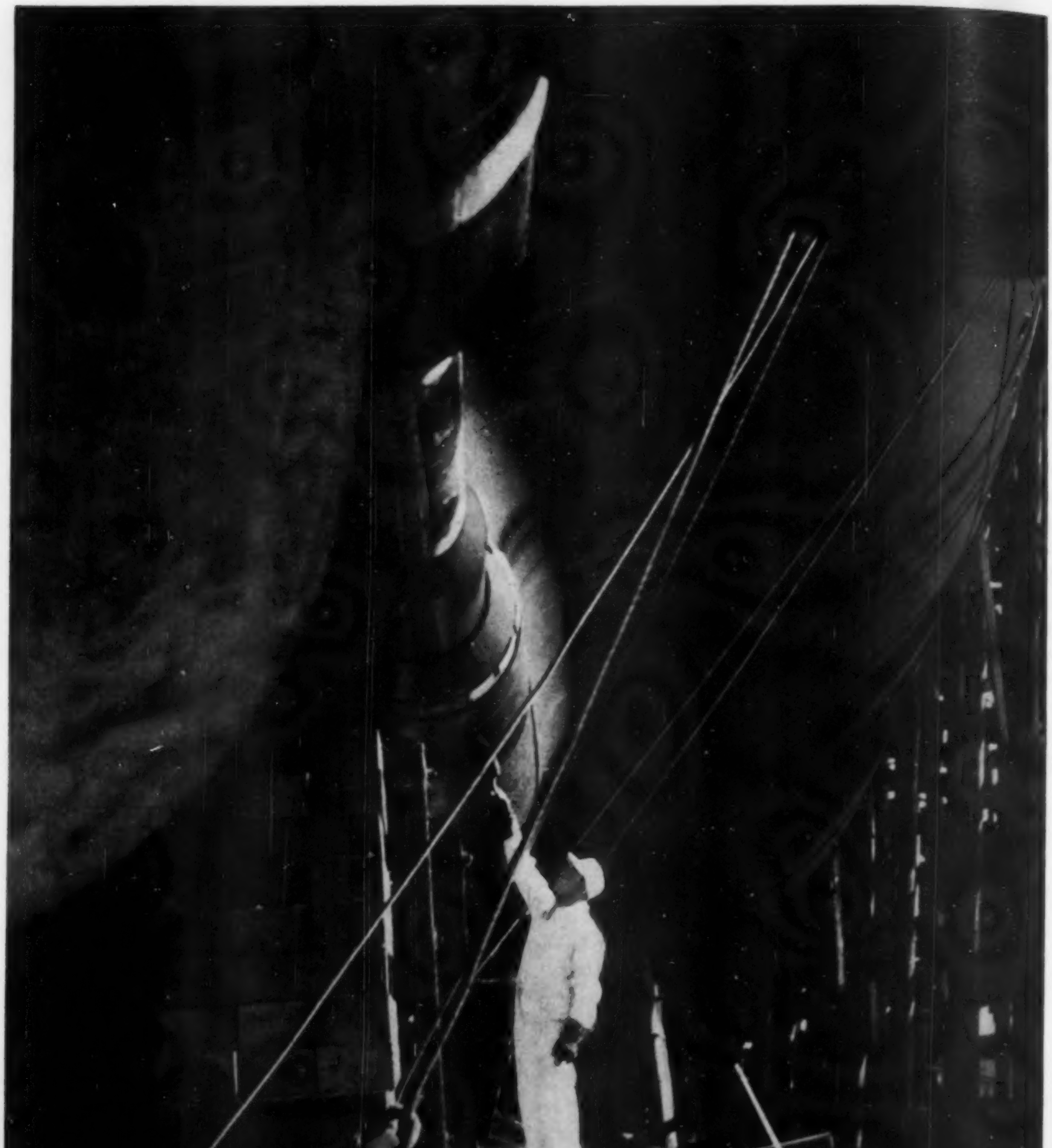
A NEW DEPARTMENT in Montreal's Dominion Engineering Works (staff almost entirely feminine) is making end bearing races for aluminum propellers for aircraft. These bearings are of a molybdenum high speed steel, for the part is attached to an aluminum forging and the aluminum forging is later heat treated, through which the bearing must retain its hardness. Received as short lengths of thick-walled tubing, a dozen flat rings are parted from each by high speed abrasive wheels. Machined to shape they are heat treated in atmosphere furnaces, and finally ground. Electrolytic etching of a small spot is necessary to check the hardened structure microscopically for freedom from segregated carbide. And, oh yes, 100% magnaflux.

Bearing races of high speed

ONCE UPON A TIME a nation which was at war wanted a bigger and better engine to fly bigger bombers further, and to wreck devastation on its enemies, but the engine manufacturer looked over his technicians and found no one who knew much about engine bearings other than how to install them, so he telephoned to the boss of the leading bearing factory and said, "Behold, we need bigger and better bearings but know not how to get them other than to tell you what we need." So the engineers and metallurgists at the bearing factory pooled their lifetime experience in making good bearings and shortly thereafter delivered bearings that excelled anything they had ever made before. Thereupon the production of bigger and better bomber engines waxed, to the great discomfiture of Tojo and Hitler and to the utter dissolution of Mussolini, until one day an inspector arose from among the multitude and said, "Hold, it is not meet, nor according to specification which sayeth that aircraft bearings must have 20% of lead, no more than 22% nor less than 19%." And the production of bigger bomber engines forthwith was stopped, for lack of bearings which contained that much lead, no more, no less.

A fable (not so fabulous either)

Moral — Never forget that it is politically safer to meet a specification than it is to deliver the goods.



Putting on the Finishing Touches, Just Before Launching

Photo by Rittase at Newport News

Constant Heating Rate Control by the Thermocouple-Rectifier Bias Principle

By R. J. Smith
Assistant Professor of Metallurgical Engineering
Michigan College of Mining & Technology, Houghton, Mich.

THE CONSTANT ENDEAVOR of researchers and scientists in commercial and college laboratories to develop new ideas, processes and materials and to produce better equipment has led to the development of various types of equipment designed to eliminate, as nearly as possible, all variables which have a bearing on the results of research. A typical example of a successful development is the control of constant temperature by various commercial thermostats and controllers based on the "on-off" or the "bias" principle. Such control is claiming the attention of researchers in the field of physics, physical chemistry and physical metallurgy. As one example of the utility to researchers, the advantages to be gained in thermal analysis by the changes in physical properties as temperature changes at a constant rate are obvious.

Various devices, some ingenious, have been invented to approach or obtain constant heating and cooling rates. The principle of operation has varied from the resistance control of amperage (as in the simple resistor-furnace combination) to the grid bias control of amperage through an electronic tube (as in the thyratron tube for the same purpose). Even the on-off control of amperage to a furnace has met with considerable success for furnaces with greater heat capacity, as in the program control of commercial equipment described in the literature published by instrument companies such as Wheelco Instruments Co. and Leeds and Northrup Co.

The disadvantages of the variable resistance for the control of the amperage-temperature relation are that manual control must be initiated and that a specific resistor must be wound for each furnace and each heating rate of that furnace.

Some of the disadvantages have been eliminated by the Chevenard application of the "hot wire" ammeter to the control of temperature rate of change, as recommended by C. T. Eddy, head of the department of metallurgy at Michigan College of Mining and Technology. (See *Instruments* for July 1935.) However, this method has the three distinct disadvantages that it requires a set of time-temperature-amperage calibration curves for each furnace, that the sensitivity decreases to some extent at low amperages, and that the furnace load varies the above calibration.

The method described by Frank Adcock in *Journal of Scientific Instruments* for 1935, based on the control of the grid bias of a thyratron controlling tube by a potential divider acting against a thermocouple welded to the furnace heater element, is a step forward in the control of heating rate by a furnace-resistor series. The main disadvantages of his method are the complexity of operation and the tendency toward overshooting, which causes a ragged heating curve, though progressing in a straight direction.

Several other instruments have been designed to operate on the potential-divider principle, with the thermocouple in the heating chamber. (See *The Iron Age* for Nov. 5, 1942.) These methods all have the outstanding disadvantage of overshooting, except where large furnaces are used. These furnaces are usually too large for research purposes and are not versatile as regards the range of heating or cooling rate control.

A method has been devised at this institution for the control of heating and cooling rate which is based upon the combined principles of the rectifier ammeter (for anticipation of power change) and the thermocouple (for initiating power equipment to produce temperature change). Either millivoltmeter or potentiometric equipment may be used to control power controlling equipment such as resistors or auto-transformers. However, in the explanation of this principle to

Legend for All Diagrams

1—Resistance furnace
2—Shunt
3—Step-up transformer
4—Full wave bridge rectifier.
5—Auto transformer
6—Clutch wheel
7—Couple, chromel-alumel
8—DP-DT reversing or limiting relay switch
9—Gear reduced synchronous motor
10—Temperature limit cam
11—Potentiometer controller
12—Step-down relay transformer
13—Series reversing motor
14—Relay switch
15—Relay coils
16—DP-DT switch operated from relay coils
17—Resistor
18—Screw
19—Main power line shunt
20—Ammeter
21—Limit switches, normally closed
22—Worm-rotated contact arm upon which are mounted H-C, L-C and the release contacts for neutral position
23—Synchronous motor and cam for operating chopper bar
24—DP-DT relay switch for operating H-C-L of relay coils *15*
25—Temperature scale, 0 to 1200° C.

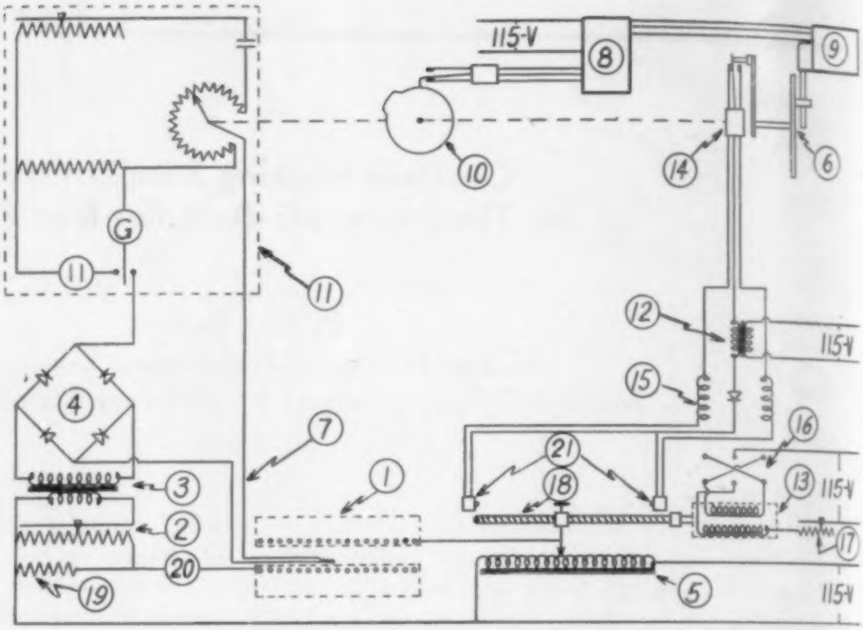


Fig. 1 — Circuit Diagram of Heating Rate Controller, Incorporating an Altered Automatic Potentiometric Pyrometer

be given below, only the potentiometric circuit will be discussed in detail.

The electrical circuit used in the potentiometric method is shown in Fig. 1. The operation of this apparatus for a heating curve is as follows:

Knowing the approximate full load wattage of the furnace *1*, the shunt *2* to the a.c. primary of the rectifier transformer *3* is set to supply about 12 millivolts from the rectifier *4* at the above wattage. (This resistor has previously been calibrated in watts, so that the adjustment is merely a matter of an initial setting.) The contactor of the auto-transformer *5* is then set to the lower voltage end. The clutch wheel *6* is moved closer to or further from the center of the clutch plate, depending on the heating rate desired. This clutch wheel likewise has previously been calibrated for heating rate in degrees per minute, so that only an initial adjustment is necessary; in this instrument this calibration is for a chromel-alumel couple *7*. The reversing or limit switch *8* is now turned on and adjusted to cause the gear-reduced synchronous motor *9* to rotate the clutch wheel *6* in the proper direction for heating. At the same time the desired temperature limit or reversing

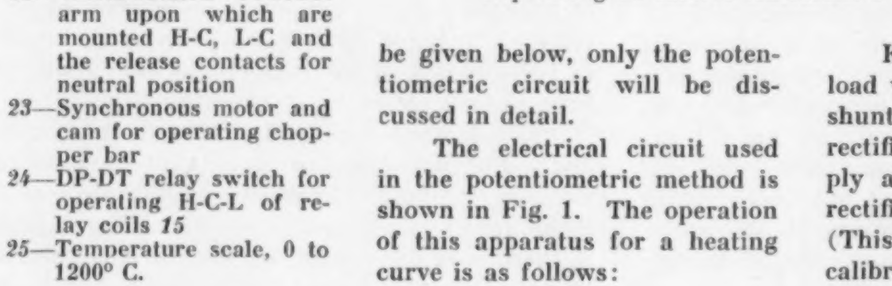


Fig. 2 — Circuit Diagram of Heating Rate Controller, Incorporating Mechanically Operated Millivoltmeter Pyrometer

temperature may be adjusted on the cam *10*.

The controller *11* (previously standardized against the standard cell), the relay transformer *12*, the series reversing motor *13* and the power to the auto-transformer *5* are turned on. The contactor arm of clutch plate *6* is now adjusted to neutral position on relay switch *14*. Thenceforward the operation is automatic.

As the contactor arm of the clutch plate *6* is rotated at the desired rate, the low and common contacts of relay switch *14* make contact, energizing one of the relay coils *15*. This coil in turn closes the double-pole, double-throw switch shown at *16* and thus energizes the motor *13* (whose speed is governed by the resistor *17*). The motor, acting through the screw *18*, moves the contactor of the auto-transformer to a point where the potential supplied by the rectifier *4* plus the thermocouple *7* causes the controller shaft to rotate, thus restoring the neutral position of the relay switch *14*. As the thermocouple *7* — which is usually placed against the side of the muffle or core for convenience of research operation and sensitivity of control — begins to heat, the controller shaft is moved so that the high and common contacts of the relay switch *14* are shorted, thus reversing the motor *13* and decreasing the power to the furnace to such a point that the neutral position of the relay switch *14* is again established. Line voltage variations are similarly compensated for, the sensitive element being the combined shunts *2* and *19*, transformer *3*, and rectifier *4* assembly, whose immediate response affects the controller *11* which, through the relay system, corrects for the variation before the thermocouple is affected. The ammeter *20* is a valuable aid in adjusting the apparatus when starting from mid-temperature ranges or when starting with a furnace whose characteristics are unknown.

For changing the heating rate during a run, adjusting of the clutch wheel *6* is all that is necessary.

When the temperature limit of the run is reached, motor *9* is reversed manually or by pre-adjustment of the cam *10* which operates the reversing relay *8*. If the amperage change to the furnace in this operation is large, the position of the auto-transformer contactor is manually shifted to give lower voltage, thus aiding the series motor *13* to establish neutral position of the relay switch *14* sooner. When the auto-transformer assumes zero potential position the cooling rate can no longer be maintained unless artificial cooling mechanisms are incorporated.

For constant temperature control the furnace is brought up to temperature and the clutch wheel plate *6* adjusted to neutral position; however, for this operation the synchronous motor *9* is not utilized. The advantage of this type of constant temperature control is that the furnace is operated on a bias amperage supply as demanded by the thermocouple-rectifier combination.

The normally closed limit switches *21* are used to stop the motor *13* when the zero and 115-volt limits of the auto-transformer are reached.

Similarly, Fig. 2 is a circuit diagram of an apparatus using a mechanically operated millivoltmeter instrument as the controlling device. Figure 3 represents a circuit diagram of a similar apparatus incorporating a millivoltmeter instrument of the capacitance control type as the controlling mechanism. For constant temperature control, or constant temperature change control, the rectifier bias principle may also be used in conjunction with resistance thermometers, thermopiles, or any other device which gives almost lineal electrical variation with temperature.

All three of the instruments illustrated are based on the same fundamental principle —

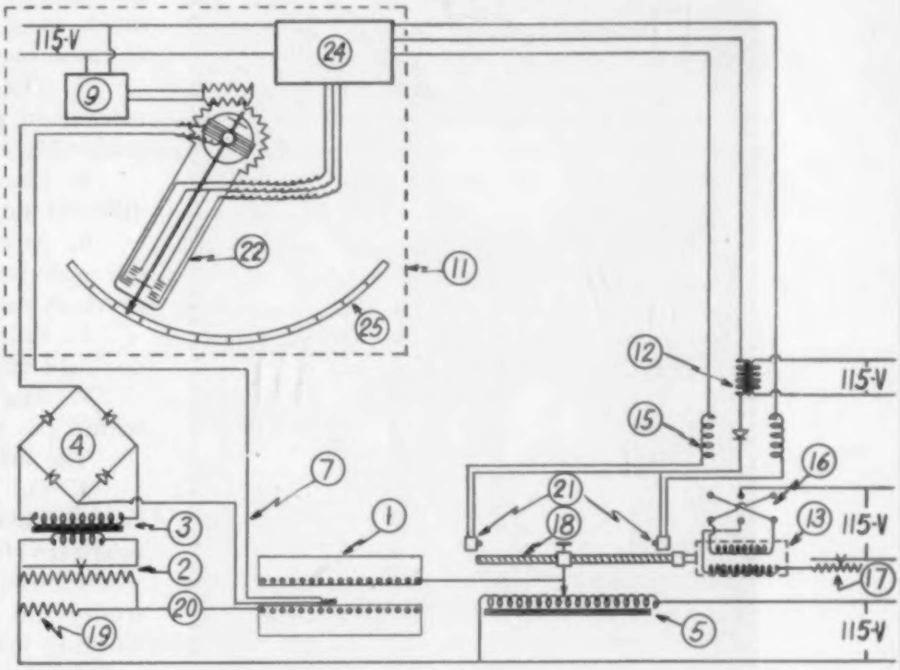


Fig. 3 — Circuit Diagram of Heating Rate Controller, Incorporating Millivoltmeter Pyrometer of the Capacitance Control Type

namely, the smooth control of power by the bias action of the rectifier of the rectifier-thermocouple assembly. A brief study of the circuits of Fig. 2 and 3 will show their similarity.

In our working model the only wires attached to the instrument cabinet are the flexible cord from the power socket, the flexible extension leads to the couple of the furnace, and the leads carrying the controlled power to the furnace.

The following advantages reside in the thermocouple-rectifier bias principle for control of heating and cooling rate:

1. Either converted potentiometric or millivoltmeter instruments may be used for controller.

2. Smooth control of temperature change results from the immediate response to power change of the shunt-rectifier of the rectifier-thermocouple combination. Speed control of the reversing motor governs the sensitivity of response; however, too much speed tends to cause over-shooting and thus to cause continuous searching.

3. The thermocouple may be inserted at any convenient place in the hotter part of the furnace, preferably against the core wall.

4. Changes in the heat capacity of the load for different heats are automatically compensated for.

5. Any furnace within the power capacity of the auto-transformer may be employed without previous calibration.

6. Rate of temperature change may be varied during a run by a simple clutch wheel adjustment.

7. The instrument can hold temperature steady within the temperature range of the controller.

The disadvantages are that:

1. On cooling, the rectifier response of the rectifier-thermocouple combination is very small at near-zero furnace amperages. However, in this small interval of temperature the search of the controller and reversing motor when the controller is working mainly from thermocouple potential is sufficiently accurate, since the cooling rate can no longer be controlled after the zero potential limit of the auto-transformer is reached. Designing shallow insulation furnaces of higher power input materially lowers the useful temperature control range when cooling.

2. Since the apparatus is designed for very versatile operation, program control would be more difficult, although not impossible.

A time-temperature curve for a 600-watt dilatometer furnace is shown alongside.

Acknowledgment — The author wishes to express his appreciation to Robert Dorr, metallurgical assistant, and to members of the metallurgical research laboratory, Michigan College of Mining and Technology, for the criticism offered and assistance rendered in this development.

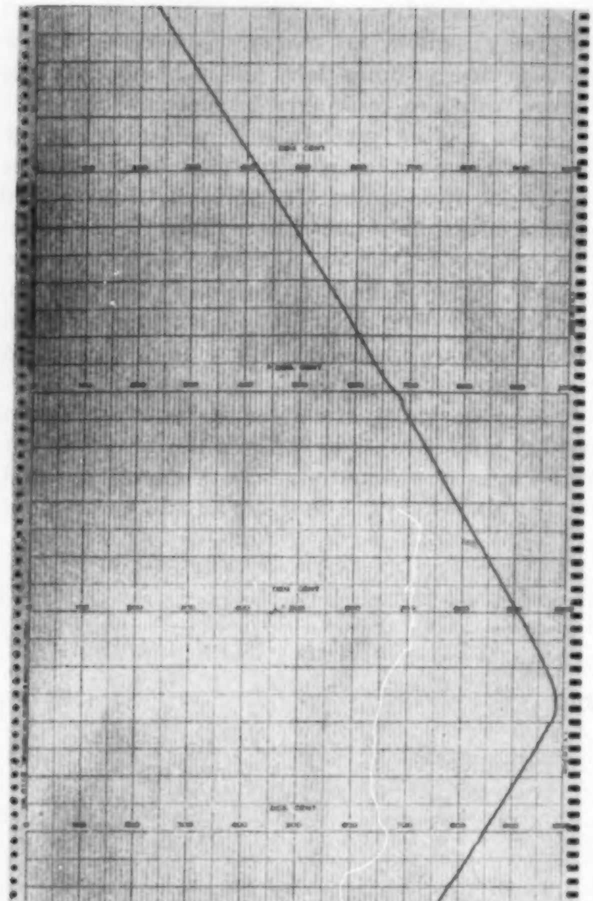


Fig. 4 — Heating and Cooling Curve of 660-Watt Furnace With the Improved Program Control. Load: 2-gram specimen of S.A.E. 1035. Purpose: Determination of Ac_1 and Ar_1 transformations at temperature change of 3.1° C. per min. (Time scale is 1 division equals 10 min.)

Spot Tests for Copper Alloys

EDITOR'S NOTE: The "Bits and Pieces" department in *Metal Progress* has proven so popular that a good many desirable notes have accumulated. However, keep them coming — an ASM book of your choice for a publishable item!

It has also been suggested that a column be devoted to "Things We Don't Know", but this would certainly take more than a column. However here's one:

How about spot tests for brasses and bronzes, to detect incidental elements like lead, iron, nickel, or even to estimate the tin content. The only one the questioner knows about is a test for phosphorus in arsenic-free copper. If a 10% HCl + 10% $FeCl_3$ solution gives a dark stain, it means "yes".

Anyone know any others?

Precision of Pyrometers

CALVIN COOLIDGE once said: "When a great many people are unable to find work, unemployment results." With equal painful regard for the truth, we may comment on the precision of temperature demanded for heat treating operations as follows: "The temperature used for a given heat treating operation must be as precise as necessary to carry out that operation successfully."

Because this sage observation may not be accepted as definitive by some skeptics, a little elaboration is in order.

There are two elements involved in measuring the temperature during a heat treating operation, the accuracy of the pyrometric system used, and the accuracy with which it is applied (that is, the care that is taken to see that the temperature *observed* is the temperature of the work).

First things first:

Thermocouples may show a deviation at 1500° F. of ± 10° from the truth; the error usually is less, and is usually proportional to the temperature. When a couple is carefully calibrated before use, allowance can be made for this thermo-electric error. Modern potentiometric pyrometers — that is, the indicating and control mechanism — will be accurate to closer than ½% when properly cared for, usually about ¼%, or say ± 5° at 1500° F. The entire heat measuring system should be accurate, then, to closer than ± 15° at 1500°, and, since the errors are rarely maximum and not always in the same direction, ± 8° at 1500° F. (or ± 5° at 1000° F.) is a reasonable accuracy *for this factor.*

There are few if any operations on steel which require anything like this precision. In this day of grain-growth-controlled steels, hardening temperatures may be from 25 to 150° above Ac_3 with safety; annealing, normalizing, tempering, carburizing temperatures are certainly not critical to closer than ± 15° if repeatedly held. (Most heat treatments are set up on the basis of repetitive success, not the absolute temperature level of precise experimentation.)

Solution treatment of the light alloys of aluminum and magnesium requires good but not difficult precision. For 24S, for example, a range of 910 to 930° is stipulated. One may suspect that if highly accurate temperature control were employed, the upper limit could be set at 950°.

METALLURGICUS

Weights of Tubing

WE NOTE on page 97 of the July 1943 issue of *Metal Progress* a note from William H. Cramer regarding the weights of tubing. The author states there may be such a formula as he presents, but that he has never seen it in a handbook.

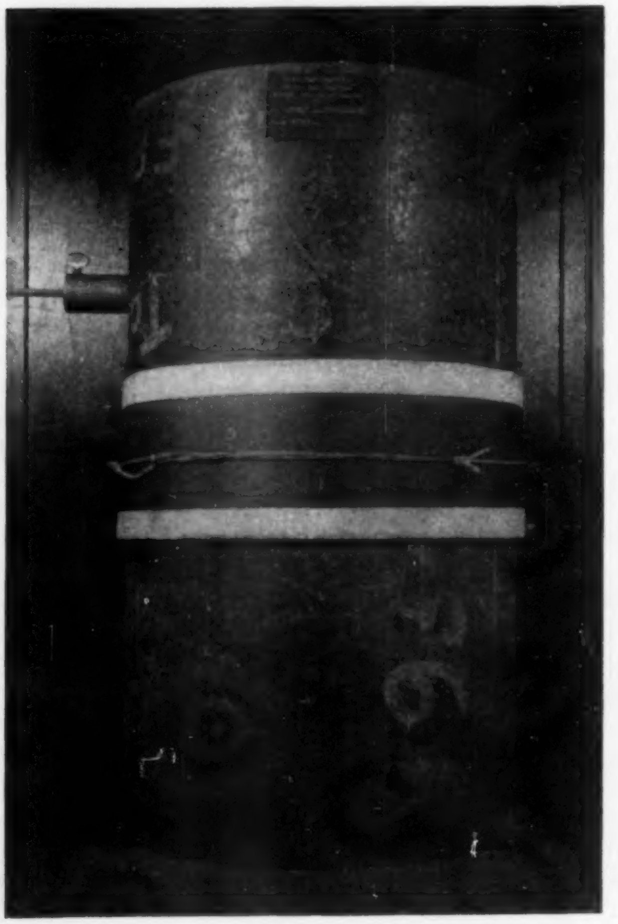
For the past 30 or 40 years, the National Tube Co.'s Pipe Standards Handbook and Shelby Steel Tube Handbook have used the formula given below for weights of steel tubing:

$$W \text{ equals } 10.680158\ (D - t)t$$

The constant in this formula is based on the weight of steel as 0.2833 lb. per cu.in. Since this National Tube Co. formula has been used almost universally for many years in calculating the weight of steel tubing, we believe the slightly different formula given in Mr. Cramer's note may cause some confusion, as his would give a weight approximately 1% less than that which has been so long a virtual standard. (E. C. WRIGHT, Assistant to President, National Tube Co.)

Handling Film for Radiography

ABOUT five years ago we developed some ideas on the handling of film for radiographic testing that have enabled us to do much field work with greater expedition. We had gotten tired of using medical film, 14 by 17 in. maximum size, when inspecting long seams on pressure equipment, with the attendant troubles in identification, edge overlap, and matching. Using radium as a source, centrally located within a pipe or vessel, it was apparent that a long roll of film



could be wound clear around the object, and one exposure would suffice.

It was decided that it would be most desirable to obtain film of some width convenient to the maker, in rolls 50 or 100 ft. long. Film could then be cut to the length desired for each exposure. However, no exposure holders or processing fixtures were available so both had to be devised and constructed. It was likewise necessary to obtain screens.

For holders, ordinary heavy black paper was obtained, 36 in. square. (Where longer holders were needed, paper was firmly joined with rubber cement.) Paper of the desired length was cut 15 in. wide and accurately folded so that two overlapping flaps covered a 5-in. wide receptacle. Edges and sealing areas were covered with adhesive tape. This exposure holder was loaded with screens made of 5-in. wide tin-coated lead or 6% antimony-lead. Hard rolled aluminum sheet about 0.008 in. thick served to stiffen the entire assembly, an expedient found necessary especially when the soft pure lead, tinned, was used as screening material.

The loaded exposure holder or cassette was then placed around the pipe which carried such identification figures and penetrameters as desired. Only 2 in. overlap was necessary. Exposure was then made in the regular manner. The figure shows an exposure holder held firmly in place by a stout cord with heavy rubber band take-up. In field work, such fastening has served to hold cassettes in place without fail for many hours. The fixture for holding and centering the radium is in place at the left. In one emergency, purchase of kodak and movie film in a local photographic supply store saved several days delay, and produced adequate X-ographs. (ALEXANDER GOBUS, Metallurgist, Sam Tour & Co., Inc.)

Preventing Quench Cracks in Toolsteel

ONE SOURCE of trouble in heat treatment of high speed tools comes from sawing up an old tool or splitting a larger bar down its center. It is far better to forge the bigger piece about to size and so keep the segregate in the center. Center segregate, appearing on the surface, is a likely cause of cracks.

Decarburized surfaces also cause cracks, in my experience. Much toolsteel has it, unless $\frac{1}{32}$ to $\frac{1}{16}$ has been machined from the surface, and treated in controlled atmosphere or salt bath.

The worse the steel warps, the more it cracks. To minimize warpage I like a double preheat (soak at 1000° and at 1525° F.). Air blast quench is fine for most high speed, and also helps cut down warpage and segregate cracks. (MICHAEL V. CHIOVARE, Tool and Die Hardener, Forge Plant, Dodge Chicago.)

Determining Chromium in Alloy Steel

WHEN running chromium on a lot of alloy steels, certain ones, noticeably nitralloy and some 52100 samples, do not dissolve completely after the nitric acid addition. It was formerly the practice to re-weigh and re-run these using perchloric acid. Instead, we use the following

modification: If, after addition of nitric acid, any of the chromes are not clear yellowish-green, but retain a muddy-black cloudiness from insolubles, add 5 ml. of 48% hydrofluoric acid and continue heating for 5 min. or until the solution is clear. Finish with persulphate and hydrochloric acid as usual. In addition to being able to run these difficultly soluble samples right in the regular run, we find that we can use standard sample No. 72b containing 0.962% Cr. This is the only standard available now containing 1% chromium, and one should be able to run the standard along with the samples. (WILLIAM TEITEL, Head Chemist, and GLEN W. DICKEN, Chemist, Transue & Williams Steel Forging Corp.)

A Newer Method

CHROMIUM and vanadium can be determined rapidly and accurately in all steels by the simple expedient of boiling the sulphuric-nitric solution with 5 g. of potassium chlorate per test. No filtrations are required and no perchloric acid. The reaction is

$$Cr_2O_3\,(SO_3)_3 + 2\,KClO_3 + 4\,H_2O\,(SO_3) =$$
$$2\,CrO_3\,(SO_3)_3 + K_2O\,(SO_3) + 2\,ClO + 4\,H_2O$$

The chromium and vanadium are finished in the usual manner by titrating with N/20 ferrous ammonium sulphate and N/20 $KMnO_4$. (CHARLES MORRIS JOHNSON, Chief Chemist, Park Works, Crucible Steel Co. of America.)

Crackless Plasticity in Gear Teeth

METALLURGISTS, as well as other citizens, need new words to describe new ideas, but sometimes the new words are poorly chosen or applied incorrectly. As an example of the latter, the author was studying some worn out gears and pinions made of S.A.E. 4140 steel, flame hardened, and that very evening ran across the following sentence in an article purporting to define the ideal physical condition: "Metallurgists must produce a metal which will be in a condition of crackless plasticity and adjust its microstructure to the loads as applied and released."

Feathered-Out Curl at Top of Remains of Gear Tooth on Badly Worn S.A.E. 4140 Steel. Flame hardened surface has completely worn away, and ferrite and pearlite crystals have ironed out into fibers

The writer of this sentence should first have seen one of the above-mentioned gears, teeth three-quarters worn away, and with outer edge curled over. The micro below, at 100 diameters, right in this curl, shows that the microstructure had adjusted itself to the loads; no cracks could be found in any locations. Despite the possession of the property of "crackless plasticity" to a superlative degree (at least in the literal sense of the term) the gears had to be replaced with others having quite different characteristics.

By the way, the new ones are functioning satisfactorily. (JAMES L. AVIS, Consulting Metallurgical Engineer, Seattle.)

Direct Positives for Micrographs

WE ARE saving much time in our overworked metallographical laboratory by exposing direct positive paper rather than making the usual transparent negative and printing from it. Total time for a wet print is about 15 min. against 2 hr. for a negative and print. Three months' use have convinced us that the method is fast, reliable and economical, and can be recommended for non-ferrous alloys which can be etched to show good contrast, and for uses where only one or two prints are needed.

Any standard direct positive paper may be used; we use the Eastman Direct Positive Paper S.S. with recommended processing, except that a solution of ⅓ glycerine, ⅓ alcohol and ⅓ water serves as an after bath to obtain a better contrast on drying.

The steps and timing required are as follows:

1. Exposure — 6 sec. is about average for our work.
2. Development — 1 min.
3. Wash — 15 sec.
4. Bleach — 30 sec.
5. Wash — 15 sec.
6. Clear — 30 sec.
7. Wash — 15 sec.
8. Redevelopment — 45 sec.
9. Wash — 15 sec.
10. Standard acid fixing powder — 30 sec.

This totals to a treatment time of 4¼ min. Then comes after-wash of 10

Wall of Brass Cup, Photographed in Direct Positive (75X) in a Study of Grain Size Vs. Anneal

min., and a glycerine soak of ½ min., a grand total for a wet print of 14¾ min.

The prints should be blotted after the glycerine soak. The drying time is negligible if the paper is pre-coated with a water-proofing agent so that only the emulsion gets wet. After blotting the print may be used immediately.

As in the conventional process, several prints may be processed at one time so that the average time may be decreased greatly; 5 min. was the timed average in a recent group of micrographs taken.

Results compare favorably with the negative-positive process in the rendition of detail but there is very little control of contrast except by etching. For grain size studies of brass the ammonium hydroxide, hydrogen peroxide etch is very satisfactory.

The paper cost is approximately one fourth that of the same size negative and printing paper. This is a relatively minor matter, but the increased speed and decreased cost of the process have resulted in the much freer use of micrographs in our work. (J. K. Fox and R. A. Smith, Metallurgy Department, Fulton Sylphon Co.)

Shear Tester for Spot Welds

THE OPERATOR who desires to check the strength and soundness of spot welds he is about to make can readily do so by using a small shear testing machine. Spot welding is usually tested by "pulling a button", but this only tells if the material actually welded. To find the strength and soundness normally requires the service of a laboratory technician.

Through the use of the simple machine illustrated, the operator or an inspector merely takes two standard test pieces, cleans their surfaces and makes the weld by overlapping. The specimen is then clamped in the end vises, and the force applied by the hand crank is shown in pounds on the dial at the left end of the machine. A prepared chart shows the minimum strength required for various thicknesses and types of materials. (E. Stolte, Manufacturing Engineer, Westinghouse Electric & Mfg. Co.)

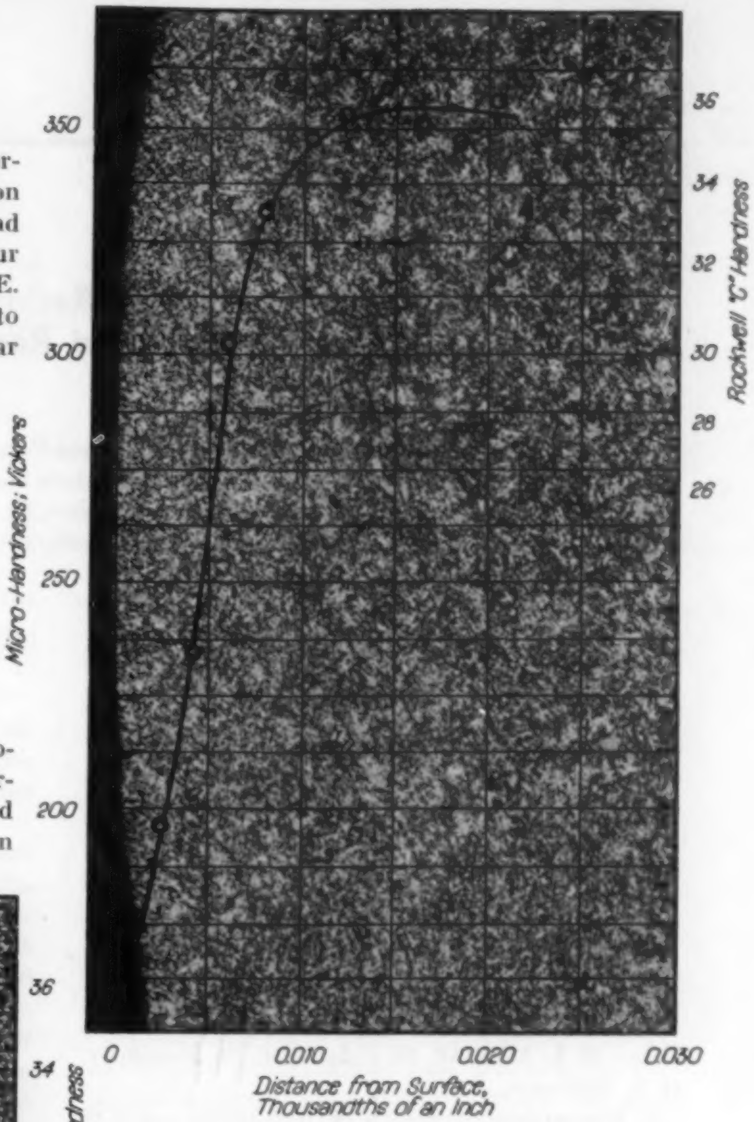
Portable Hand-Power Tester for Pulling Spot Welded Specimens

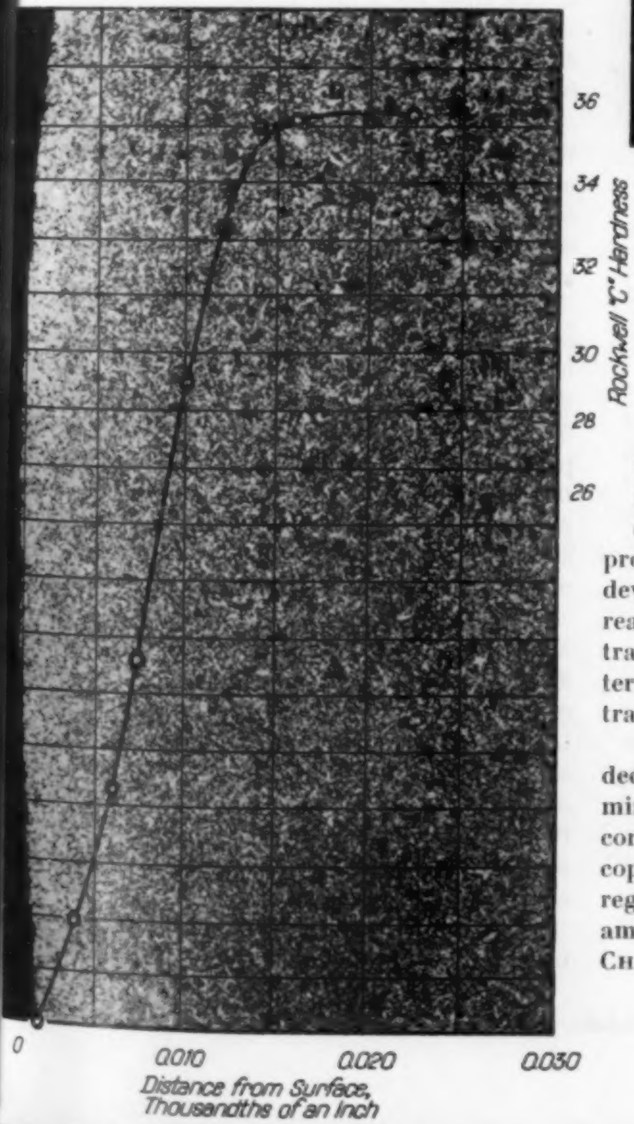
Measuring Decarburization

SIMILAR to the difficulty encountered by Merrill A. Scheil in measuring decarburization (see *Metal Progress*, May 1943), we too have had trouble in distinguishing carbon changes. Our perplexity arose when cold drawn bars of S.A.E. 4042 were to be heat treated to Rockwell C-31 to 36. We assumed that if we heat treated the bar stock without decarburizing, danger might be expected to a depth at least equal to the minimum specified hardness when measured by a Vickers micro-hardness traverse (Vickers 310).

Extreme care was taken against further decarburization during heat treatment; samples were copper plated, enclosed in a container with spent carburizing compound, oil quenched from 1500° F., and immediately tempered at 975° F. for 30 min. This yielded core hardness of Rockwell C-35.

The engraving at right shows one micro-hardness traverse. Minimum specified properties, as measured by hardness, were not found until a point 0.007 in. below the surface had been reached. Although the photomicrograph of the sample in the "as received" condition shows what we considered to be *no* decarburization, actually the micro-hardness traverse indicates the presence of 0.007 in.





The curve at left shows another heat treated piece of the same material, inspected as received by microscope and reported "partially decarburized for 0.008 in." Minimum specified properties measured by micro-hardness were not developed until a depth of 0.011 in. had been reached. The micro agrees better with the hardness traverse. Further experimentation gave even better correlation between microscope and hardness traverse when decarburization was greater.

Therefore, we feel that in steels where surface decarburization is slight, microscopic inspection minimizes this condition; small changes in carbon concentration will not be discernible by the microscopist, because diffusion from the unaffected region is too gradual to be read accurately, and amounts reported are likely to be too small. (R. D. CHAPMAN, Metallographer, Chrysler Corp.)

Machinability Ratings of Metals and Cutting Fluid Recommendations

By O. W. Boston, Professor of Metal Processing, University of Michigan,
H. L. Moir, Asst. Chief Products Engineer, The Pure Oil Co.,
W. H. O'dacre, President, D. A. Stuart Oil Co.,
and E. M. Slaughter, Metallurgist, Republic Steel Corp.

THIS PAPER is a revision and amplification of a report on cutting fluids made in 1940, which had wide circulation and general acceptance. The above mentioned authors constitute a subcommittee of the "Independent Research Committee on Cutting Fluids", organized in 1937 by Joseph Geschelin, Detroit Editor for *Automotive Industries* and other Chilton Co. publications. The entire personnel is as follows: O. W. Boston, M. A. Dixon, H. M. Fearon, Floyd Fritts, Joseph Geschelin, *Chairman*, C. B. Harding, Raymond Haskell, W. D. Huffman, J. F. Kennedy, W. H. Kildow, H. E. Martin, B. B. Mears, R. J. McWilliams, H. L. Moir, W. H. Oldacre, E. M. Slaughter, G. L. Summer.

Recommendations on cutting fluids apply to commercial practice. In the endeavor to simplify and to make more clear the use of a table of recommendations which can be used to apply cutting fluids to various processes, involving different metals, the metals themselves in the tables on pages 624 and 624A are first listed in groups in accordance with their machinability ratings. A wide variety of ferrous and non-ferrous metals have been rated individually and then arranged in six classes as follows:

Ferrous Metals	Non-Ferrous Metals
Class 1; 70% or over	Class 5; 100% or over
Class 2; 50 to 70%	Class 6; below 100%
Class 3; 40 to 50%	
Class 4; below 40%	

This machinability rating is averaged to the nearest 5% from various users' estimates, and is based upon 100% as the rating of A.I.S.I. steel specification B1112, cold rolled or cold drawn, when machined with a suitable cutting fluid at 180 ft. per min. under normal cutting conditions. The ratings are based on steels in a cold drawn condition. Metals that have been heat treated or processed in any way other than cold drawn will, of course, have different machinability ratings.

It is important to note that because of the favorable price differential many users prefer hot rolled steels for many purposes. The effect of hot rolling may be expressed very briefly as:

1. In steels containing up to 0.30% carbon, cold rolled or cold drawn bars have better machinability than hot rolled bars.

2. In steels containing from 0.30 to 0.40% carbon, there is little difference in machinability between cold rolled and hot rolled bars.

3. In steels containing over 0.40% carbon, the hot rolled material has superior machinability over the cold rolled or cold drawn. It is recommended that plain carbon steels over 0.40% carbon and alloy steels over 0.30% carbon be annealed for machining.

The range of Brinell hardness values for each of the ferrous materials given in the table on page 624 is intended to provide the most desirable limits for normal machinability and, in general, describes the commercial practice in filling steel purchase orders. It is generally accepted practice that the limiting value of hardness for normal machinability is of the order of 355 Brinell, although many steels are now being machined in mass production at hardnesses of 400 or more.

A similar classification has been given to machining operations in the table on page 624A, arranging them in order of their severity. For example, the most severe operation, No. 1, is internal broaching, and the easiest, No. 10, is sawing. This table indicates the severity of the operation, and the cutting fluid recommendation for each metal classification. The attention of users of this table is called to the following general notes on cutting fluid selection:

1. A few preferred recommendations printed in bold face type are based on general practice

observed by the committee members and reported from the survey it conducted. They are intended to serve only as a guide to the choice of a cutting fluid. It must be remembered, however, that a cutting fluid should be selected for the individual operation, the material being machined, the tool material, size and shape, and the conditions of operation, such as speed, depth of cut and feed, and the results desired in tool life, chip formation and finish, all being factors in the final decision.

2. It is important to keep in mind that the function of this report is to correlate recommendations from general use and practice, together with suggestions for each specific cutting problem (such as, for example, milling A 3140 steel in its annealed condition). These recommendations represent the average practice of the majority of users of cutting fluids when normal operating conditions are maintained.

3. It is possible to determine the proper cutting fluid for these normal operating conditions by referring to the table on page 624A. For example, a normal milling operation, where the operating condition is within the limits specified by the manufacturer of the machine and the steel, will come under Classification 6 as given in the table. However, if a deeper cut, higher cutting speed, or heavier feed are desired, it will become necessary for the user to be guided by the table in placing the operation in the proper classification for severity, and note the cutting oils recommended for the more severe operation.

4. The cutting fluid recommendations must of necessity be confined to types of fluids, rather than the products or brand names of individual suppliers. This should be remembered in the purchase of such fluids, as there may be quite a difference in effectiveness between two fluids of the same type on a given machine operation, owing to different manufacturing techniques of the producers thereof.

5. It is possible to subdivide this classification considerably further and perhaps make it more specific. However, such a break-down of operations with various cutting fluids, together with feeds, cutting speed, depth of cut, makes the analysis bulky and unwieldy. In many instances such a list of recommendations would be very difficult for the lay user of cutting oils to interpret.

6. Generally speaking, mineral-lard oil and sulphurized oil mixtures of low sulphur percentages are interchangeable.

7. Sulphurized oils have a tendency to stain certain non-ferrous metals, such as copper and its alloys.

8. Certain materials such as carbon tetrachloride, chloroform and other volatile solvents should not be added to cutting fluids, as harmful physiological effects might follow.

9. In the machining of aluminum, quite often cutting oils are diluted with kerosene or mineral seal oil with satisfactory results. Kerosene, up to 15%, is frequently added to emulsions to improve the quality of the finished surface.

10. Magnesium and its alloys are usually machined with mineral seal oil or dry. A supply of powdered asbestos should be kept handy to smother a fire, just in case. Tools should be kept sharp and heavy feeds used. Chips should not be permitted to accumulate on the machine.

11. In machining brass, which shows no change in cutting pressures with various cutting fluids, it is advisable to apply a cutting fluid to function as a coolant. Inasmuch as most free-cutting brass is machined in automatic screw machines, an oil is advisable to lubricate the moving parts of the machine. A paraffin or light mineral oil may suffice, or the mineral oil blended with 10% fatty oil may be used to advantage.

12. In turning Monel metal it has been found that an emulsion gives a slightly longer tool life than a sulphurized mineral oil. However, the latter breaks up the chips.

13. In general, cutting fluids should be applied in large quantities at the highest velocity possible without splashing, directly onto the tool point where the chip is being formed. From 3 to 5 gal. for each single-point tool is most effective; particularly when carbide tools are used the cutting fluid should flood the tool before the start of the cut and be applied continuously during the cut. Rapid change in temperature is injurious to most tools. The use of sulphurized oils on carbide tools is reported to be injurious to the tools.

14. Cutting fluids should be kept cool, either through the use of sufficient volume or through cooling agencies. For satisfactory tool life the temperature of the fluid should not exceed 110° F.

15. Cutting fluids should be kept clean — free from chips, bacteria, and high acidity.

16. Oils should be used on complicated machines where the lubrication of the machine, such as tool slides, must be provided for. On some jobs, such as milling and drilling, the lubrication of the chips in the flutes or chip space is an important factor in chip removal.

17. On high-speed operations, cooling is more important than lubrication, inasmuch as the speed itself usually provides good surface quality. On low speeds where the segmental or discontinuous type of chip is formed, the face of the tool may be periodically lubricated so that oils, and particularly a sulphurized oil for threading and broaching, are desirable.

Machinability Rating of Various Metals

By Independent Research Committee on Cutting Fluids

MACHINABILITY ratings are classed in four groups for irons and steels and two for non-ferrous alloys. Machinability is rated to nearest 5%, based on 100% rating for A.I.S.I. steel B1112, cold rolled or cold drawn Bessemer screw stock, machined with suitable cutting fluid at 180 ft. per min. under normal conditions as to tool life and surface finish. Hardness values indicate a desirable range and correspond to ordinary commercial deliveries.

*Denotes steel in mill-annealed condition.

(a) Numbers denote A.I.S.I. compositions, see page 666. For NE steels see page 672.

(b) High chromium-iron alloys, A.I.S.I. Type No. 416 or 430F.

(c) Spheroidize annealed by mill.

(d) A.I.S.I. Type No. 303; 18-8 of free machining type.

Class I, Ferrous, Rating 70% Plus

Specification *(a)*	Rating	Brinell
C 1110	85%	137 to 166
C 1115	85	143 to 179
C 1117	85	143 to 179
C 1118	80	143 to 179
C 1120	80	143 to 179
C 1132	75	187 to 229
C 1137	70	187 to 229
C 1022	70	159 to 192
C 1016	70	137 to 174
B 1111	95	179 to 229
B 1112	**100**	**179 to 229**
B 1113	135	179 to 229
A 4023	70	156 to 207
A 4027*	70	166 to 212
A 4119	70	170 to 217
Malleable (Ferritic)	100 to 250	120 to 200
(Pearlitic)	70	190 to 240
Cast steel (0.35% C)	70	170 to 212
Stainless "iron" *(b)*	70	163 to 207

Class II, Ferrous, Rating 50 to 65%

Specification	Rating	Brinell
C 1141 *(a)*	65	183 to 241
C 1020	65	137 to 174
C 1030	65	170 to 212
C 1035	65	174 to 217
C 1040*	60	179 to 229
C 1045*	60	179 to 229
A 2317	55	174 to 217
A 3045*	60	179 to 229
A 3120	60	163 to 207
A 3130*	55	179 to 217
A 3140*	55	187 to 229
A 3145*	50	187 to 235
A 4032*	65	170 to 229
A 4037*	65	179 to 229
A 4042*	60	183 to 235
A 4047*	55	183 to 235
A 4130*	65	187 to 229
A 4137*	60	187 to 229
A 4145*	55	187 to 229
A 4150*	50	187 to 235
A 4615	65	174 to 217
A 4640*	55	187 to 235
A 4815	50	187 to 229
A 5120	65	170 to 212
A 5140*	60	174 to 229
A 5150*	55	179 to 235
A 5045*	65	179 to 229
NE 8024	60	174 to 217
NE 8124	55	174 to 217
NE 8233*	60	179 to 229
NE 8339*	60	179 to 229
NE 8620	60	170 to 217
NE 8630*	65	179 to 229
NE 8724	65	179 to 229
NE 8739*	60	179 to 229
NE 8744*	55	183 to 235
NE 8749*	50	183 to 241
NE 8817	60	170 to 229

Class III, Ferrous, 40 to 50%

Specification	Rating	Brinell
C 1008 *(a)*	50	126 to 163
C 1010	50	131 to 170
C 1015	50	131 to 170
C 1050*	50	179 to 229
C 1070*	45	183 to 241
A 1320	50	170 to 229
A 1330*	50	179 to 235
A 1335*	50	179 to 235
A 1340*	45	179 to 235
A 2330*	50	179 to 229
A 2340*	45	179 to 235
A 3240*	45	183 to 235
A 4340*	45	187 to 241
A 6120	50	179 to 217
A 6145*	50	179 to 235
A 6152 *(c)*	45	183 to 241
A 9260*	45	187 to 255
NE 8442*	45	187 to 255
NE 8447*	40	187 to 255
NE 8949*	50	187 to 255
Ingot iron	50	101 to 131
Wrought iron	50	101 to 131
Stainless *(d)*	45	179 to 212
Cast iron	50	160 to 193

Class IV, Ferrous, Rating 40% or Below

Specification	Rating	Brinell
A 2515*	30	179 to 229
E 3310*	40	170 to 229
E 52100 *(c)*	30	183 to 229
Ni-Resist*	30	
Stainless 18-8*	25	
Manganese oil hardening steel *(c)*	30	
Toolsteel, low tungsten, chromium and carbon *(c)*	30	
High speed steel *(c)*	30	
High carbon, high chromium, toolsteel *(c)*	25	

Class V, Non-Ferrous, Rating Above 100%

Alloy	Rating
Magnesium alloys	500 to 2000
Aluminum, 11-S *(e)*	500 to 2000
2-S *(e)*	300 to 1500
17-S *(e)*	300 to 1500
Brass, leaded	150 to 600
yellow	200
red	200
Bronze, lead bearing	200 to 500
Zinc	200

Class VI, Non-Ferrous, Rating Less Than 100%

Alloy	Rating
Gun metal	60
Bronze, manganese	40
Copper, cast	70
rolled	60
Nickel	20
Monel metal, cast	35
rolled	45
"K" Monel	50
Inconel	45
Everdur	60

Recommended Cutting Fluids for Normal Machining Operations

By Independent Research Committee on Cutting Fluids; Joseph Geschelin, Chairman

Severity	Type of Machining Operation	Ferrous Metals; Steels and Irons: I; 70% Plus*	II; 50 to 70%*	III; 40 to 50%*	IV; Below 40%*	Non-Ferrous Metals: V; 100% Plus*	VI; Below 100%*
1. (Greatest)	Broaching; internal	Em. Sul. *(a)*	**Sul.** *(b)* Em.	**Sul.** Em.	**Sul.** Em.	MO. Em.	Sul. ML.
2.	Broaching; surface	Em. Sul.	**Em.** Sul.	**Sul.** Em.	**Sul.** Em.	MO. Em.	Sul. ML.
2.	Threading; pipe	Sul.	**Sul.** ML.	Sul.	Sul.		Sul. *(c)*
3.	Tapping; plain	Sul.	Sul.	Sul.	Sul.	Em. Dry	Sul. ML.
3.	Threading; plain	Sul.	Sul.	Sul.	Sul.	Em. Sul.	Sul.
4.	Gear shaving	Sul. L.	Sul. L.	Sul. L.	Sul. L.		
4.	Reaming; plain	ML. Sul.	ML. Sul.	ML. Sul.	ML. Sul.	ML. MO. Em.	ML. MO. Sul.
4.	Gear cutting *(d)*	Sul. ML. Em.	Sul.	Sul.	Sul. ML.		Sul. ML.
5.	Drilling; deep	**Em.** ML.	Sul. **Em.**	Sul.	Sul.	MO. ML. Em.	Sul. ML.
6.	Milling; plain	**Em.** ML. Sul.	Em.	Em.	Sul.	Em. MO. Dry	Sul. Em.
6.	Milling; multiple cutter	ML.	Sul.	Sul.	**Sul.** ML.	Em. MO. Dry	**Sul.** Em.
7.	Boring; multiple head	**Sul.** Em.	**Sul.** Em.	**Sul.** Em.	Sul. Em.	K. Dry Em.	Sul. Em.
7.	Multiple spindle automatic screw machines and turret lathes; drilling, forming, turning, reaming, cutting off, tapping, threading	Sul. Em. ML.	Sul. Em. ML.	Sul. Em. ML.	Sul. ML. Em.	Em. Dry ML.	Sul.
8.	High speed, light feed automatic screw machines; drilling, forming, tapping, threading, turning, reaming, box milling, cutting off	Sul. Em. ML.	Sul. Em. ML.	Sul. Em. ML.	Sul. ML. Em.	Em. Dry ML.	Sul.
9.	Drilling	Em.	Em.	Em.	Em. Sul.	Em. Dry	Em.
9.	Planing, shaping	**Em.** Sul. ML.	**Em.** Sul. ML.	Sul. **Em.**	**Em.** Sul.	Em. Dry	Em.
9.	Turning; single point tool form tools	Em. Sul. ML.	Em. Sul. ML.	Em. Sul. ML.	Em. Sul. ML.	Em. Dry ML.	Em. Sul.
10. (Least)	Sawing; circular, hack	Sul. ML. Em.	Sul. Em. ML.	Sul. Em. ML.	Sul. Em. ML.	Dry MO. Em.	Sul. Em. ML.
	Grinding; 1. plain	Em.	Em.	Em.	Em.	Em.	Em.
	2. form (thread, etc.)	Sul.	Sul.	Sul.	Sul.	MO. Sul.	Sul.

Symbols for Cutting Fluids

K.—Kerosene.
L.—Lard oil.
MO.—Mineral oils.
ML.—Mineral-lard oils.
Sul.—Sulphurized oils; see note *(a)*.
Em.—Soluble or emulsifiable oils and compounds.
Dry—No cutting fluid.

Notes: *Machinability rating based on 100% for cold drawn Bessemer screw stock (specification B 1112).

(a) Oils containing both sulphur and chlorine when carefully manufactured and sponsored may be used where sulphurized oils are indicated.

(b) Preferred recommendations are in **bold face** type.

(c) In threading copper, palm oil is frequently used.

(d) It is reported by several observers that emulsions are usually unsatisfactory on some precision machines, like Fellows gear shapers and Gleason gear generators.

Salt Bath Heating

Hardening High Speed Taps and Dies in the Electric Salt Bath

By Paul C. Farren
Chief Metallurgist, Greenfield Tap and Die Corp.
Greenfield, Mass.

IT HAS BEEN SAID that the main characteristic of specialization is extreme conservatism or inflexibility. This has not been true metallurgically of late, as may be seen in the wide adoption of high speed steels in which molybdenum was substituted for tungsten to a greater or less extent.

Prior to the present war, the development of molybdenum high speed steels was hampered because consumers complained of non-uniform performance. In the light of recent experience, it is believed that such complaints were a direct result of difficulties encountered in heat treatment and not of inherent characteristics of the steels. The necessity for conserving tungsten gave the necessary impetus to the development of satisfactory heat treatment of the molybdenum high speeds. Almost overnight the toolsteel, machine tool, and small tool industries accomplished a transformation; heat treatment evolved from methods using protective coatings, through controlled atmospheres, to the modern salt bath. Phases of it are worth recording at length because its effects are likely to be permanent and have general influence on metallurgical practice.

Conversion by the Greenfield Tap and Die Corp. to a production based on high and intermediate types of molybdenum high speed steels for small and large taps, dies, and other tools is merely representative of the industry. It was obvious from previous experience that heat treatment might easily have proved the bottleneck. This was avoided by using electric salt bath furnaces of the closely spaced electrode (Ajax-Hultgren) type in order to minimize distortion and eliminate surface defects, and more especially to meet demands for tools of the cut thread type (that is, completely finished prior to heat treatment) which could not have been handled so satisfactorily by any other means. Cut thread tools account for about 25% of our production.

While virtually all methods and types of equipment are available at the Greenfield plants, for the carbon steels as well as high speeds, this paper will deal with observations made while hardening molybdenum steels, using preheat, high heat, and quench salt bath furnaces as a group under a single hood (Fig. 1) with an average capacity of 6000 pieces an operator in eight hours, and as high as 15,000 pieces on a single shift with two operators. This total is based on a variety of taps, most of $\frac{5}{16}$-in. diameter and smaller. (Actual sizes run from No. 0 machine screw taps, 0.061-in. diameter, up to 7-in. diameter.) High speed acorn, round, and spring dies are similarly treated.

In addition to some 18-4-1, steels include the 6-6-2 (intermediate molybdenum) and Mo-Max (high molybdenum), with the latter predominating. Raw material consists of bar stock, ground, cold drawn, or hot rolled. Sizes of ground drill rod run from 0.073 to 0.256 in.; cold drawn steels range from 0.275 to 2 in.; hot rolled material from $\frac{5}{16}$ to 4 in.; and forgings in larger sizes.

While intrinsic red hardness of a definite alloy cannot be affected by the method of heat treating, and while enough material is left on the body of ground thread taps to permit corrective grinding, the hardening method does largely determine tool life, wear, and general usefulness in the field, besides influencing all subsequent operations such as straightening, flute grinding, and finish grinding. In the case of a cut thread tap, no corrective grinding is possible after heat treatment. Distortion, surface effects, size, or angle changes must be held to a minimum. There is a commercial O.D. tolerance of 0.0025 in. on a ¼-in. tap, a lead tolerance of ±0.003 in. per in.

of thread length; angles must be held to within 68 min. (included angle) and pitch diameter to 0.002 in. total tolerance. Lead and pitch diameter are of major importance, and there have been no cases where dimensions could not be readily held in salt bath practice.

Handling Technique

Up to the time it reaches the hardening room, each tap has been a unit production problem, involving 25 operations like burring, centering, fluting, shank grinding, and inspection. The heat treater now handles up to 75 units at a time in the preheat bath.

Standard taps run from 1⅝ to about 3⅝ in. long up to $\frac{9}{16}$ in. diameter. Regular taps, ½ in. and smaller, are handled in baskets while taps over ½ in. and including 1½ in., and extra-length taps with up to 15 in. of thread length, are suspended vertically. Sometimes this may be a truly selective hardening. All taps greater than standard length, as well as those over 1½-in. diameter, are handled in spring tongs or suspended by wires or eyebolts.

Some special fixtures and baskets used at the Greenfield plant for salt bath hardening practice are shown in Fig. 2 to 4. The smaller perforated baskets of cold rolled steel last for approximately 100 full immersion cycles in the high heat.

The preheat furnace, controlled at 1550°F., is rated at 22 kw. although its input is rarely much over 18, or 80% of capacity. It consists of a ceramic pot 14 in. in diameter by 20 in. deep, having two 2-in. square parallel electrodes immersed to within a few inches of the bottom for heating and circulating the salt. Bath level is kept to within approximately 2 in. of the rim at all times. Immersion time for each charge of taps has been worked out on a basis of size, quantity, and method of handling, and is recorded on a heat treatment sheet such as shown on page 630. Salt

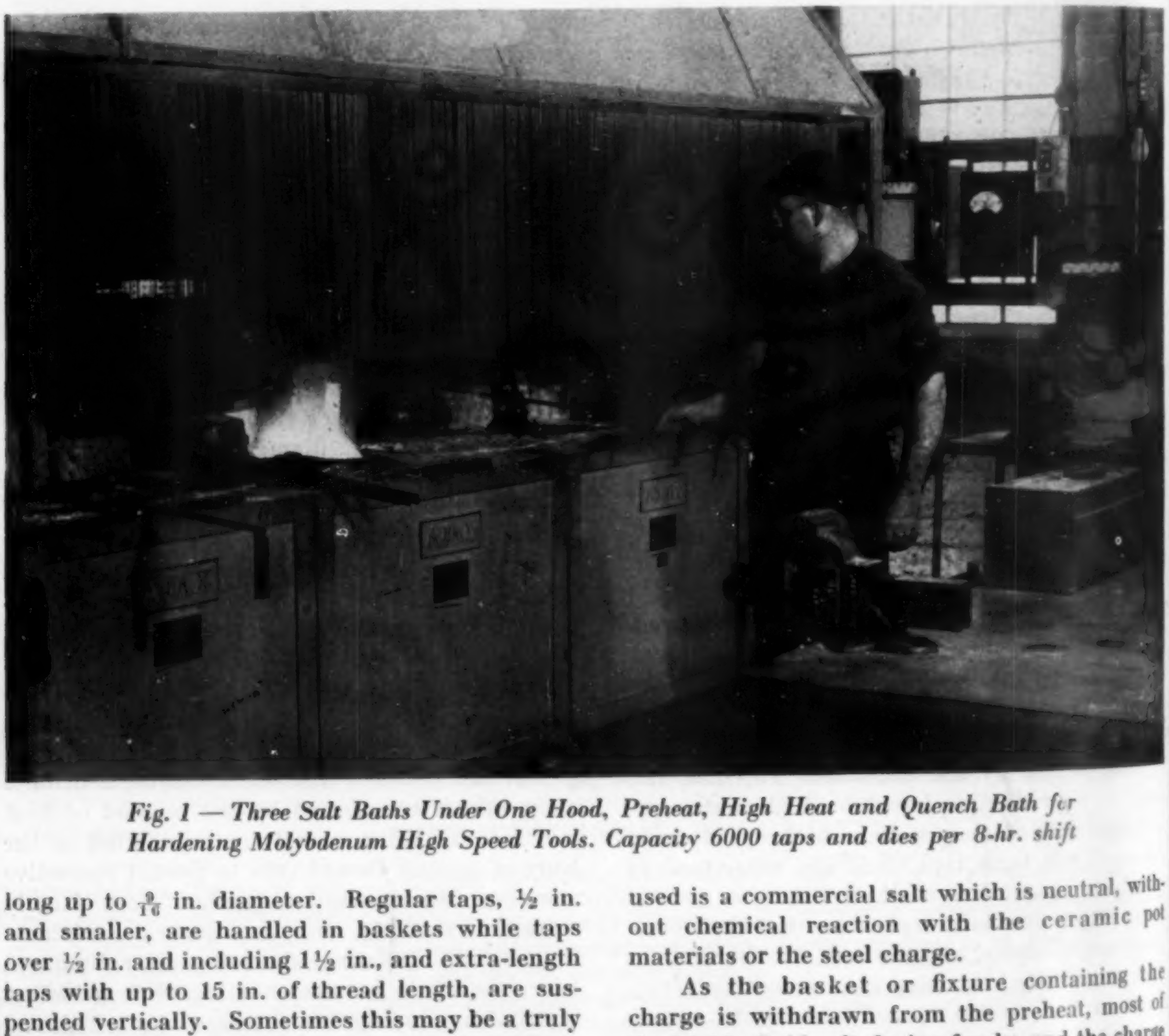


Fig. 1 — Three Salt Baths Under One Hood, Preheat, High Heat and Quench Bath for Hardening Molybdenum High Speed Tools. Capacity 6000 taps and dies per 8-hr. shift

used is a commercial salt which is neutral, without chemical reaction with the ceramic pot materials or the steel charge.

As the basket or fixture containing the charge is withdrawn from the preheat, most of the highly fluid salt drains freely, and the charge is then immersed in the high heat bath contained in a ceramic pot 12 in. in diameter by 20 in. deep, heated by immersed electrodes and controlled at 2180° F. The salt used — similarly neutral to

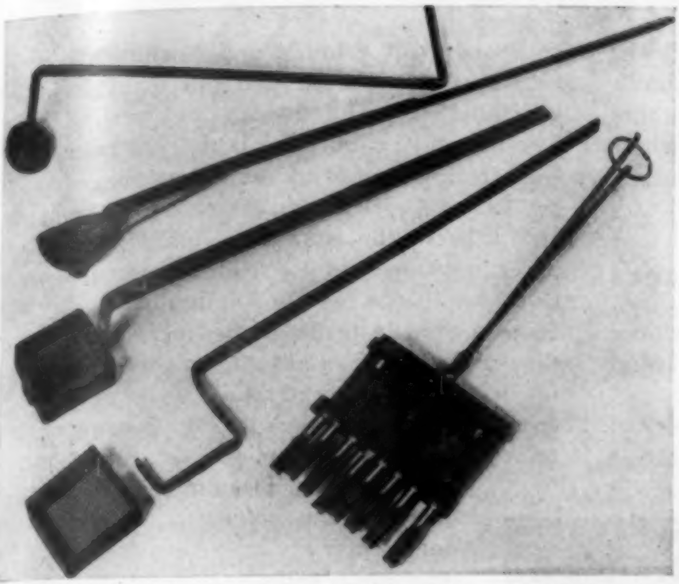


Fig. 2, 3, and 4 — Hardener's Tools. Above is fixture for 10 long-shanked taps, sludging ladle, immersion baskets for small items, and spring tongs. At right is simple hanger for large taps with axial hole. In lower corner are stubby tools suspended in a group

refractory pots — is highly fluid, requires no rectifier, and no instance of decarburization or oxidation has been recorded in hardening many hundred thousands of taps and dies. This bath is desludged or cleaned periodically to avoid breakdown of the various salts because of carry-over from one bath to the other.

The fixture load of work is held in the high heat for a specified time and emptied into the salt bath quench — that is, the fixture itself is not transferred with the charge, thus avoiding transfer of the quench salt to the preheat or high heat baths. Inside the electric quench furnace pot, which is 14 in. diameter by 20 in. deep and heated by immersed electrodes to 1150 to 1200° F., is a perforated basket for catching the work (shown in Fig. 5).

Alongside the quench furnace is the oil bath for final cooling, containing another basket, usually rectangular, readily removable to keep the various sizes and types of tools separate. The cooling oil, circulated between the cooling and storage tanks by overflow and centrifugal pump, is a non-saponifiable mineral oil, with no fatty acid content, a type which avoids "soap reactions" with the protective salt film or drag-out carried over on the tools.

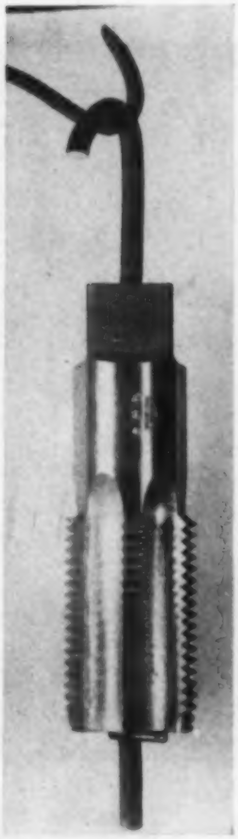
Following the oil bath, there is a plain hot water rinse. If salt does not wash freely, it is an indication that high heat salt has begun to build up in the quench furnace because of carry-over on the tools. It is then necessary to bail out 10 to 15 lb. of quench salt and make up with new additions of fresh quench salt.

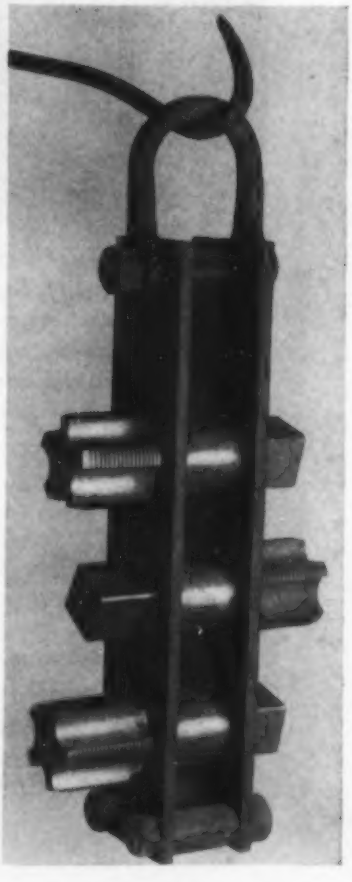
Tempering and Straightening

The tools are tempered at least twice, one hour or more each time, at 1050° F. for all molybdenum types. Either forced convection or salt bath furnaces are used, with an air cool to room temperature after each tempering.

Finish is always bright when salt is used throughout, but if scale is present following air tempering, as it usually is, pickling is necessary. The taps are then inspected for cumulative distortion, straightened, and tested for hardness.

Regardless of hardening equipment available and limitations of handling incidental to each type, the ratio of length to diameter is itself a factor in distortion, and the subsequent need for straightening. Work done in the salt bath, particularly long tools, usually requires less straightening than if "atmosphere hardened", unless inherent stresses are already induced by the production operations, such as might occur in stamping. Long tools are ordinarily picked up and laid down on a furnace floor, and this invariably results in unnecessarily high distortion.





It appears that the salt bath produces the minimum distortion of all methods available when handling complicated shapes, or where length is out of proportion to diameter, or where distortion is almost inherent in the handling methods necessary.

Furnace Operation and Maintenance

Temperature control is of utmost importance when hardening high speed steels, and somewhat lower temperatures are utilized in salt baths.

Automatic equipment used for our battery of pots is shown in Fig. 6. The high heat bath is equipped with a Leeds and Northrup Rayotube recording pyrometer, with Micromax indicating controllers for the quench and preheat baths. The Rayotube calibration is checked twice during each shift, by removing the thermopile casing and sighting an optical pyrometer down the pyrometer tube to the working depth of the bath in order to get an accurate reading under true black-body conditions, as shown in Fig. 7. Thermocouples used in preheat and quench are 14-gage Chromel-Alumel. Calibrated couples are made up in advance so that those in use may be corrected immediately or replaced. Because of their relatively low temperatures, preheat and quench couples need checking only once daily. Straight chromium-iron alloys or refractory materials have been found best for protection tubes.

Overnight or idling temperatures are 1200° F. in the preheat, 1850 in the high heat, and about 1050 in the quench furnace. Automatic alarms announce any failure of power or controls. It is customary for the watchman to set the controls so as to allow 30 min. for all baths to come up to temperature for the first shift. When idling, the furnaces are covered against radiation loss with refractory covers, one for each unit.

An adjustable chain curtain runs the length of each furnace group, and above is the fume hood, vented with an 18-in. pipe and blower to the open air. No particular difficulty with heat or fumes is encountered with this arrangement. The temperatures involved are high, however, and elbows or sharp bends in the vent pipe are to be avoided. Temperature-drop in the high heat is

Fig. 5 — Draining Quench Salt From Basket of Taps. Perforated basket squared at rear to avoid touching electrodes which carry in the current for heating

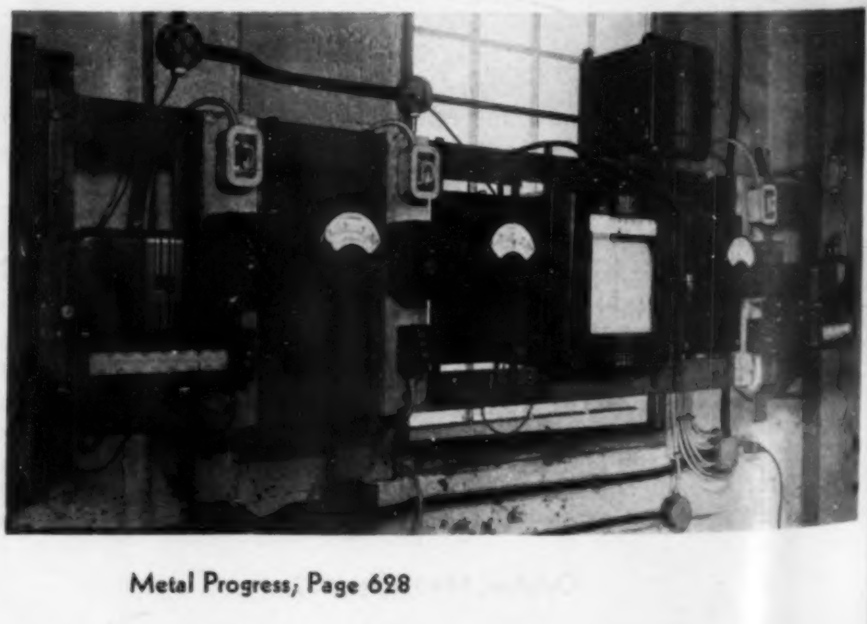


Fig. 6—Automatic Indicating and Recording Pyrometers, and Controllers for the Triple-Pot Installation (See Fig. 1)

slight during production, being less than 5° for 5 lb. of charge. "Anticipating controllers" prevent over-shooting during rapid recovery, and because of the electromagnetic circulation of the bath and the internal heating effect of the electrode spacing, it is possible to hold temperatures within a 5° maximum variation.

Heat resisting alloy electrodes, free from nickel, have an average life of 1200 hr. in the high heat furnace. During this period, the electrodes are usually lowered three times, maintaining proper immersion depth for highest efficiency and compensating for wastage. Six years' experience with electric salt baths has shown that nickel will plate out on immersed tools no matter what experimental salt or recommended combination of salts may be used. Consequently, the nickel or high nickel alloys must be excluded from pots, electrodes, protection tubes, or handling fixtures. In an emergency it has been found perfectly feasible to use 18-4-1 high speed steel for such items; it gives long service life, but the drawbacks because of cost and a lack of available sizes and lengths are obvious.

In operation at Greenfield Tap & Die Corp. we find that salt drag-out is moderate, either when hardening unfinished tool blanks or prethreaded taps. Steady (though not always peak) production is the rule. Salt additions are made each shift, separate pans being used for each of the furnaces as shown in the table below.

Maximum estimated drag-out checks closely with salt replacement figures, and discloses a 1 to 2% ratio to pounds of work hardened, calculated for basket fixtures having a certain amount of drag-out in themselves. In general, this ratio holds for high output (up to 20,000 taps a day for each furnace) except that where two operators handle the work on a single shift there may be a slight occasional increase in salt additions, since two men have opportunity to clean, bail, and desludge more thoroughly. This drag-out is extremely low, considering the smallest No. 0 machine screw taps are 0.061 in. in diameter, with as many as 80 in a single immersion.

Typical Salt Additions and Cleanings

	Preheat	High Heat	Quench
Weight of salt	6.5 lb.	8 lb.	5.5 lb.
Additions, 1st shift	3 pans	3½ pans	2 pans
2nd shift	1½	1½	1½
3rd shift	2½	5 — Desludge	1⅔
1st shift	1½	2½	4 — Desludge
2nd shift	4 — Desludge	5 — Desludge	2½
3rd shift	1½	2½	2½
1st shift	3	3½	2½
2nd shift	1½	1½	1½

Fig. 7 — *Optical Pyrometer Sights Down Ceramic Tube to Measure the Bath Temperature and Thus Check Indications of Rayotube Head (Shown Detached, on Front of Furnace Casing)*

The cleaning ladle has a reinforced handle to stiffen it at the high temperatures. The operator "sounds" the pot, feels the sludge while scraping the side, and lifts it up from the bottom. This sludge is a greyish, viscous matter, and it consists mostly of metallic oxides from the high heat and preheat, with cyanates, carbonates, oxides, and unmelted high heat salt removed from the quench.

Cleaning operations seem to affect pot life more than any other factor, since there is little erosion otherwise. This is true of the high heat furnace where conditions are severe; the original diameter of 12 in. will in time increase to 14 or 15 in. At that time, well over a year, the efficiency drops, the total volume of salt becoming somewhat larger than can be handled by the power input. This is partly because of increased surface radiation.

Metallurgical Inspection

Following the operations already described, representative tools are taken for file test, Rockwell hardness, and metallographic examination. Before the heat treater starts on an order of tools,

Salt Bath Heat Treatment

ORDER NO. 1/9682F DATE 8/16/43

CUSTOMER -------

DESCRIPTION H.S. Cut Thread Plug Taps

SIZE 1/4 - 20 NO. 500 SYMBOL "DU"

PRE HEAT 1550° F TIME 2 Mins.

HI. HEAT 2200° F TIME 2 Mins.

QUENCH 1200° F OIL x

~~VERTICAL FIXTURE~~

~~SPRING TONGS~~ Basket

NO. PIECES 35 - 40

TEMPER (SALT x 1050° F - Double 1 + 1 hour
(
~~[illegible]~~

SPECIAL INSTRUCTIONS Check for lead, angle, P.D., and O.D. before proceeding.

O.K.
W.E.W.

HARDNESS

AS HARD C 65 - 65.5

AS TEMPERED C 63.5 - 64

1299

An Instruction Sheet Accompanies Each Lot

a metallurgical inspector checks the furnace temperatures; samples for hardness and fracture are also taken from the first basket or fixture. Rockwell hardness tests are supplemented by file tests, using special files of C-67 to 70 Rockwell to "touch" the chamfer of cut thread taps or the body of ground thread taps. (No matter what the hardness of the tap, or what the record of success in normal use, a file will break off thread crests if drawn across them.)

Cross sections are prepared for metallographic examination of structures in the "as-hard" and tempered conditions. Specimens are likewise examined for decarburization of edges and grain growth. The austenite grain count is held within 18 to 22 Snyder-Graff*, as shown in the photomicrographs, Fig. 8 and 9. Such tests are made at the beginning of every order of regular taps, no matter how many orders may be handled. A standard Rockwell of C-63 to 65 after tempering is called for on molybdenum taps of ¼ in. diameter and over. Smaller taps are held to C-62 to 64.

General Observations

It may be noted that analytical methods fail to disclose any trace of oxidation when using the above hardening procedure. The salt is a mixture of chlorides with a self-contained rectifier. Daily replenishment is all that is required to maintain the chemical balance, hence no special analyses or separate additions are necessary. No decarburization is encountered, provided the baths are cleaned properly as described. While decarburization might result from a breakdown of the high heat salt or be caused by preheat salt carried over into the high heat bath, our observations have failed to detect it during the past 12 months, even though no rectifier has been added. Such results might be considered unusual or due to unusual personnel or laboratory facilities, except that atmosphere furnaces operated in the same plant over a long period of time disclose unfavorable aspects when hardening the molybdenum high speed steels in production.

In atmosphere furnaces, the hearth conditions vary considerably after furnaces have been in use for some time. Accumulations of scale or oxide do occur. Distortion or buckling of the hearth itself results in an irregular surface which will not support a long piece uniformly. The tools sag, attempting to conform to the contour of the hearth. That is the obvious explanation for much of the seemingly inexplicable distortion frequently encountered after hardening. Efforts to overcome this by asbestos floors, refractory trays, or other materials on the hearth have resulted in indifferent success.

There is without doubt a higher percentage of rejects in atmosphere furnace practice. Many metallurgical defects are associated with the fact that the atmosphere does not protect those parts

*The sample is etched to emphasize austenite grain boundaries, magnified 1000 dia., and the number of boundaries cut by a 5-in. random line (average of ten locations) is the grain size. See *Metal Progress*, April 1938, page 377.

of the tool in contact with the hearth or fixture. Stratification of the atmosphere near the hearth may be indicated by parts with considerable flat areas directly in contact with the hearth or the tray; defects are almost invariably produced on the tool area directly in contact with the hearth. These conditions may be aggravated depending upon the type of atmosphere. Under ideal gas control, with filters and condensers operating at maximum effectiveness, it is now clear that as low as 0.1% of CO_2 in the high heat atmosphere decarburizes molybdenum tools at times, while 0.4% and up means certain disaster. Such close control is difficult to hold. It is obvious also that with very high CO atmospheres in the preheat, carburization is rapid and uncontrollable. Such CO-rich atmospheres required for high molybdenum or Mo-Max steels are likewise very sluggish, and frequently so hazy or smoky that the operator is unable to note heating progress. This is a severe handicap because predetermined time cycles do not always produce uniform results.

If used at all, borax or other protective coatings is not a panacea, for it reacts with refractory hearths. It must also be removed from the tool, as by hand or steel shot blasting, by soaking in acetic acid, or by quenching into molten caustic soda at 900 to 1100° F. The last is preferred.

Certain fixtures, such as those of nickel-chromium, become oxidized through continuous in-and-out exposure to air when transferring tools from preheat to the high heat furnace. Such scale has a marked upsetting effect on the atmosphere in the immediate vicinity. This explains why, where gas analyses clearly indicate ideal operating conditions, tools coming through may show intolerable surface changes.

There is always a relatively low yield from atmosphere furnaces where direct comparisons may be made on production. This is due largely to the human element and also to the time consumed in loading fixtures, furnace regulation, and the greater heating time required. Discounting all other factors, our time sheets showed an average loss of 1 to 1½ hr. a shift.

Having all these considerations in mind it has become apparent that the electric salt bath offers the simplest and most effective means at the disposal of the metallurgist for hardening high speed molybdenum steels. Correct procedures not only accomplish all that might be expected of atmosphere furnaces at their best, but likewise perform many operations that cannot be handled adequately in any other way. Operators of less experience can turn out consistently superior work, in comparison with operators of greater experience using the more complicated atmosphere furnaces.

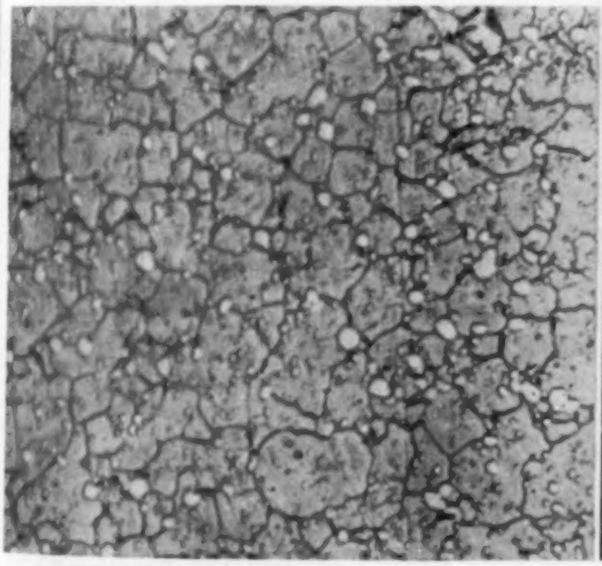


Fig. 8 — High Molybdenum, High Speed Steel "as Hardened" to Rockwell C-65. Snyder-Graff grain size 19

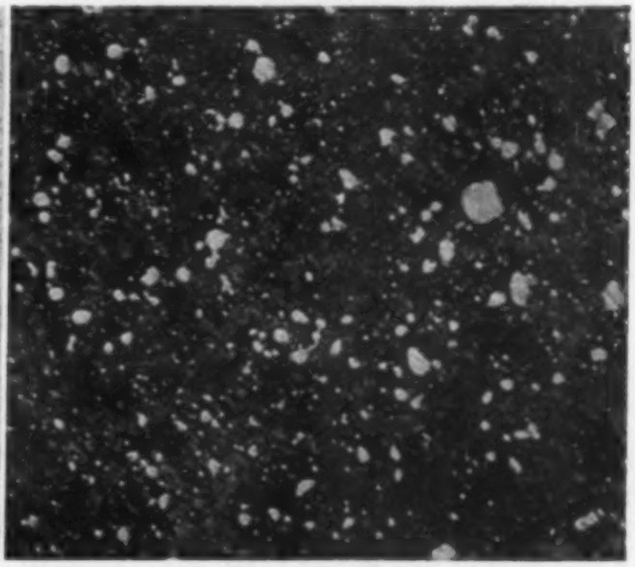


Fig. 9 — Same After Tempering Twice for 1 Hr. at 1050° F. to Rockwell C-64. Both micros at 1000 dia.

All evidence indicates that it would be possible to select almost any average man or woman and teach them the successful procedure for toolsteels within a week. This should not be construed to mean that the high speed salt baths are confined to the heat treatment of molybdenum steels, since they have been used with equal success for all types — with the possible reservation of higher electrode and salt costs when higher operating temperatures are necessary.

Factors Insuring Satisfactory Industrial Furnace Refractory Construction

By John Wallerius, Chief Engineer
and Frank Ericson, Supervisor of Construction
Stewart Industrial Furnace Division of Chicago Flexible Shaft Co.

EFFICIENCY and long life of industrial furnaces for heat treating and metal processing depend not only upon the proper engineering design, but also upon the refractory lining, insulation, and upon their proper installation. It has been our observation that the latter of these requirements is well worth careful consideration by top engineering personnel. Lack of experience by masons, foremen or supervisors may result in errors of construction or failure to give proper attention to important details. Either of these factors might cause serious damage to the refractory linings in service.

The instructions herein given are based upon experience gained in many years, building heat treating furnaces and observing installations in general use in various industrial operations. Although our objective has been to establish for our own engineers a standard for the proper installation of refractories in Stewart furnaces, the conclusions we have reached may well be of interest and value to all who are engaged in metal processing. While it is obviously best to avoid operating trouble by proper construction, it may happen that certain items of good mason practice may have been overlooked, and the following remarks may then be useful to the supervising metallurgist in ferreting out the cause of an unduly early breakdown. Likewise, any extensive repair should follow the same principles.

Here, in brief, are the important steps in new furnace construction, or the installation of new linings, in order to insure maximum life, minimum maintenance, and economical operation:

1. Prepare cements as required:

Fireclay: Mix with water to a smooth thick pouring consistency free from lumps.

Asbestos Cement: Mix with water to a barely pourable consistency that will adhere well to the brick.

Air Set Cement (High Temperature Bonding Mortar): This material is already mixed for laying brick. For wash coating the inner face of the lining, add water to bring it to a very thin pouring consistency.

Silicon Carbide Cement: Mix with water to a thick paste suitable for handling with a trowel.

2. Apply cement by dipping brick into it and immediately laying in place, tapping each one firmly as laid to keep all joints as thin and tight as possible.

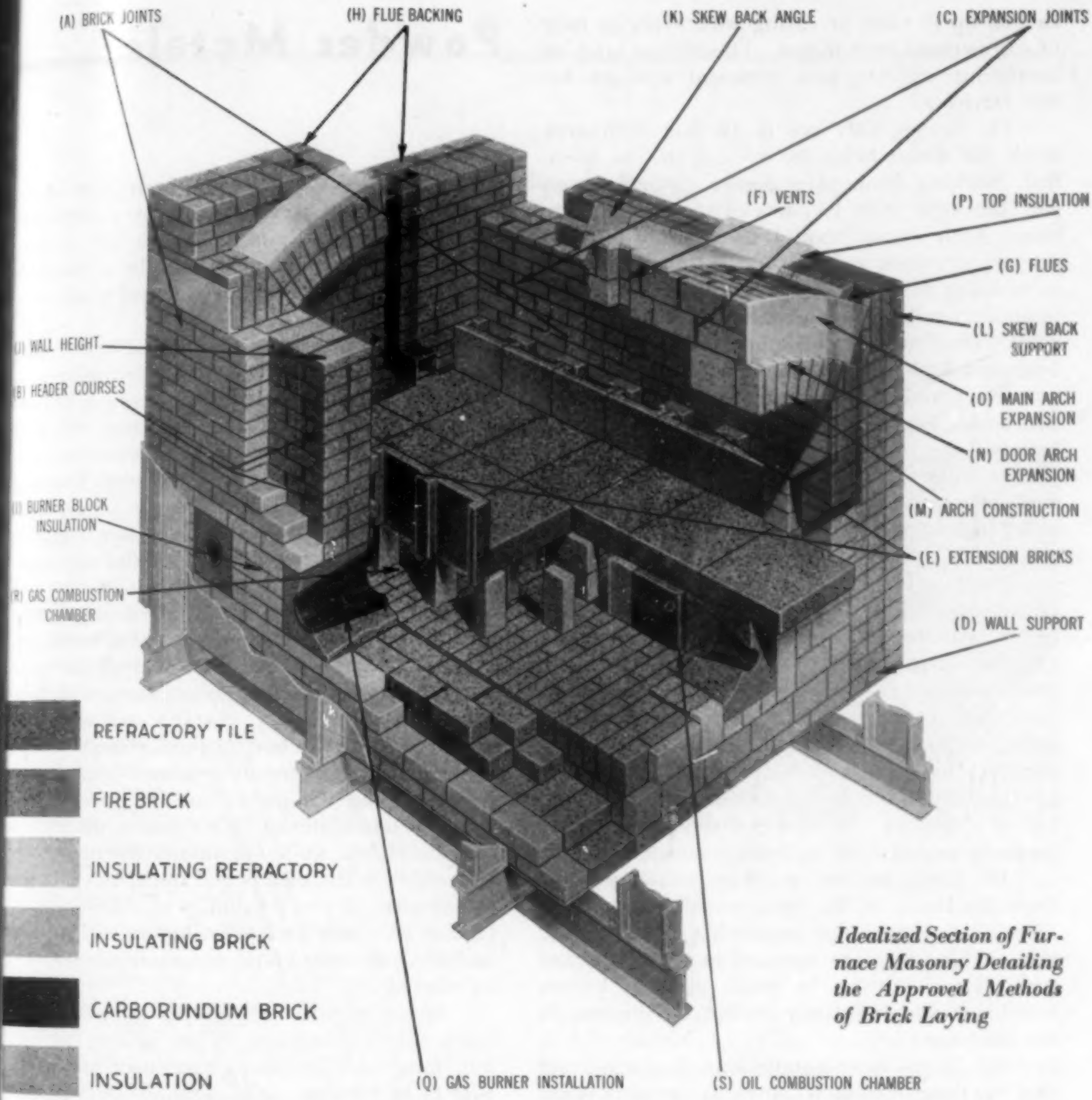
3. All brick joints must be broken as indicated at *A* of the drawing herewith. Joints in outer course of brick must not be in line with those of inner course, in order to prevent heat penetrating through them.

4. In walls of 9 in. thickness or heavier built with firebrick or insulating firebrick, a header course should be laid at least every fourth course, as at *B*.

5. Because of variation in expansion, insulating brick headers are not tied into firebrick or insulating firebrick.

6. Care must be taken in selecting only brick that are square, or of proper neat shape if wedges or circles. A stiff air-set cement paste should be used in the joints between cut brick to insure proper bonding.

7. Expansion joints must be properly spaced (see *C* on drawing), of proper width, and broken both vertically and horizontally. Spacers of cardboard or corrugated paper make good fillers for these expansion joints. Several small expansion joints evenly spaced over the length of the furnace wall are preferable to one larger joint.



Idealized Section of Furnace Masonry Detailing the Approved Methods of Brick Laying

Allow approximately 0.5% to 1% of wall length (depending on brick used) in expansion joints. No expansion joints should be allowed in insulating brick courses.

8. Firebrick walls must always be directly supported by firebrick laid on the furnace bottom or foundation. (See *D*.) Insulating brick or insulating firebrick do not have sufficient strength to support heavy walls.

9. Spacing and dimensions given on the drawings must be carefully followed both vertically and horizontally, particularly in the spacing of extension brick used to hold semi-muffle walls in place (see *E*), and in the location and size of vents *(F)* and flues *(G)*. Flues and vents must be backed up with firebrick or insulating firebrick *(H)* and not with insulating brick. Insulation or insulating brick must always be separated from burner ports by a course of firebrick or insulating firebrick *(I)*.

10. Hearth, supports, and semi-muffle walls, when of fireclay material, should be laid with air set cement, or when of silicon carbide material, with silicon carbide cement. All silicon carbide brick should be laid with silicon carbide cement.

11. Use split or 2-in. brick to adjust the final height of side and end walls (see *J*).

12. Use feather edge brick, end skews, side skews or edge skews to get proper skew back angle for arch support (see K). Skew back must be

backed up to shell or casing with firebrick only *(L)* to support arch thrust. (Insulating brick or insulating firebrick lack sufficient strength for this service.)

13. Arches *(M)* are to be laid with arch brick (or wedge brick for wide span), as specified, working from skew backs toward center. Key the arch with two bricks smoothly cut to size. Arch forms should be used to provide proper curvature and to support the arch while it is being laid. Use separate arch forms for main arch and door arch because of different arch radii. Door arches and supports should always come out flush with door jamb and arch castings or metal framing to provide proper seal with the door. An expansion space should be provided between the top of the door arch *(N)* and the bottom edge of the arch casting to allow for vertical expansion of the door arch. Large expansion joints should be provided at the ends of the main arch *(O)*.

14. For insulation of furnace arches, with or without insulating firebrick, use a heavy coating of asbestos cement mixed to a thick paste *(P)*. After the walls and the arch are installed, coat the inside of the furnace with a wash coating of air-set cement mixed to the consistency of a thin paste.

15. Installation of tunnel type gas burners is extremely important for the satisfactory operation of a furnace. Be sure that small burners are properly coated with refractory cement.

16. Large burner openings require packing from the inside of the furnace using a mandrel (see *Q*). For maximum burner life and efficiency, this packing must be rammed in very tight and particular care must be taken that the burner and block are completely packed all the way to the steel work.

17. In gas fired installations, it is important that the flame issuing from the gas burners is not obstructed by hearth supports or piers. (See *R*). In oil fired installations, it is important that a silicon carbide brick be correctly placed in front of the oil burners to baffle the flame properly and to insure thorough and efficient combustion (see *S*).

18. New furnaces or newly installed linings should be brought up to temperature very slowly to expel moisture and dry out the brickwork thoroughly. Failure to observe this precaution may result in open cracks in the lining and greatly decrease the life of the lining.

19. Carefully fill all cracks with air-set cement or, if the cracks are in silicon carbide hearth joints, fill them with silicon carbide cement.

Powder Metals

OUR LABORATORY has been working on dense metal powder parts for a number of years, but very little of this work has yet been published. However, now that the demand for dense parts is rising rapidly, some of it may be of general interest.

Several years ago we attempted to determine what physical properties could be obtained in dense nickel parts made by compression and sintering of nickel powder, in comparison with parts machined from bar stock. The necessary machining on the specific parts required much labor and loss of raw material and the use of expensive equipment. High costs resulted. It was thought that production could be simplified and costs materially reduced while still maintaining or even improving upon the necessary physical properties by employing the new art of powder metallurgy.

As the cost of the product at this time was of less importance than the establishment of physicals, the laboratory started out with what appeared to be the best method, though perhaps too expensive for general commercial application. By employing the purest nickel powder then available and sintering in a vacuum, the problem was simplified, as it eliminated the question of impurities in the metals and impurities in a protective gas. If the possibility of obtaining satisfactory results is once proved, then various other and cheaper commercial processes can doubtless be worked out.

Nickel powder (carbonyl) all passing 325 mesh was formed into ⅜-in. square test bars, 3 in. long. All specimens were made under pressure of 50 tons per sq.in., and one-third of them sintered at 900, 1000 and 1100° C. respectively (1650, 1830 and 2010° F.) for 4 hr. in a vacuum. Bars were subsequently repressed either at 50, 75, or 100 tons per sq.in. On a few of the specimens this was followed by a 12-hr. anneal in a vacuum at 500° C. (930° F.).

Analysis of the filings from these annealed bars showed the following composition: 0.082% C, 0.005% S, 0.005% Si, 0.080% Fe, and 0.050% Cu. The following elements were searched for but the chemist reported *nil*: P, Mn, Pb, Sn, Co and Al.

From among the mass of tests on these bars which had undergone various combinations of pressings, annealings and repressings, the following data are taken as representative:

Dense Nickel Parts From Metal Powder

By Charles Hardy
President, Hardy Metallurgical Co., New York

Izod Impact Tests

Treatment	Energy
Pressed at 50 tons per sq.in., Sintered at 900° C. (1650° F.), Repressed at 100 tons per sq.in.	3.8 ft-lb.
Pressed at 50 tons per sq.in., Sintered at 1000° C. (1830° F.), Repressed at 100 tons per sq.in., Annealed at 500° C. (930° F.) for 12 hr.	8.9 ft-lb.

Tension Impact Tests

Treatment	Tension Impact	Elongation
Pressed at 50 tons per sq.in., Sintered at 1100° C. (2010° F.), Repressed at 50 tons per sq.in.	24 ft-lb.	20%
Pressed at 50 tons per sq.in., Sintered at 1000° C. (1830° F.), Repressed at 100 tons per sq.in.	23 ft-lb.	16%

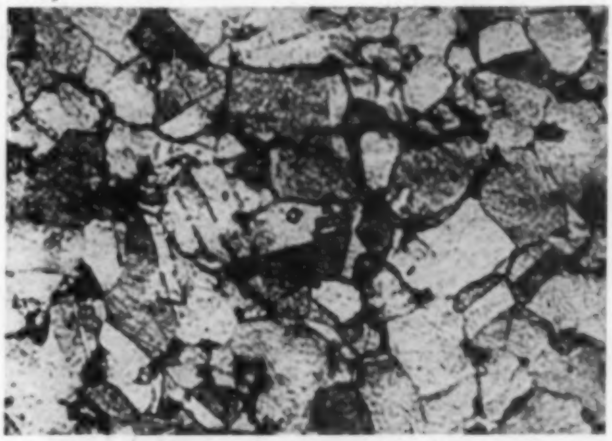
Static Tensile Tests

Treatment	Ultimate Strength	Elongation
Pressed at 50 tons per sq.in., Sintered at 900° C. (1650° F.), Repressed at 100 tons per sq.in.	96,000 psi.	2%
Pressed at 50 tons per sq.in., Sintered at 1000° C. (1830° F.), Repressed at 50 tons per sq.in., Annealed at 500° C. for 12 hr.	44,000 psi.	8%

Density

Treatment	Density
Pressed at 50 tons per sq.in., Sintered at 900° C. (1650° F.), Repressed at 50 tons per sq.in.	0.286 lb. per cu.in. (See micro)
Pressed at 50 tons per sq.in., Sintered at 1000° C. (1830° F.), Repressed at 100 tons per sq.in.	0.302 lb. per cu.in.

Density of wrought nickel varies from 0.311 to 0.321 lb. per cu.in. A comparison of densities indicates that the nickel produced from metal powders after repressing at 50 tons per sq.in. had 89 to 92% of the density of wrought material, and the nickel produced from metal powders after repressing at 100 tons per sq.in. had 94 to 97% of the density of the wrought material.



Grain Struc ure, Magnified 500 Diameters, of Specimen Produced From Nickel Powder; Compacted at 50 Tons per Sq.In., Sintered 4 Hr. in Vacuum at 900° C. (1650° F.), anl Repressed at 50 Tons per Sq.In. Density of sample is 90% that of wrought nickel

Rockwell hardness varied about 5%, whether repressed at 50 or at 100 tons per sq.in.

The photomicrograph illustrates typical grain structure of these dense nickel specimens produced from metal powder.

A total of 44 bars was prepared and sent to other laboratories for checking against our results, and the above is a fair picture of the group of returns. It will be seen that the tests are close enough to established standards to justify further work, particularly in a commercial plant.

When it is considered what great advances have been made in the techniques of powder metallurgy since these tests were made, it is to be expected that parts made from nickel powder will be added to the ever-increasing number of applications of this art, once war restrictions are removed from the use of nickel.

Representative Micrographs of Copper-Base Alloys

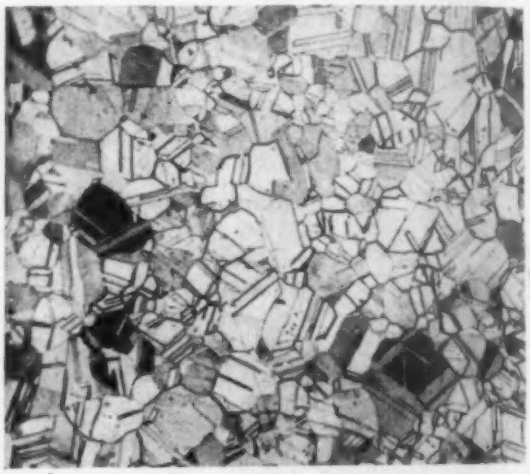
From the files of the
Technical Department, The American Brass Co.

THE STRUCTURE of the wrought copper-base alloys such as brass, bronze and nickel silver, revealed by polishing and etching before microscopical examination, is of importance in many manufacturing operations. After the initial breakdown and annealing operations, the grain or crystal structure can be controlled by regulating annealing furnace temperatures. Strength and hardness are further governed by the amount of cold work subsequently applied to the annealed material.

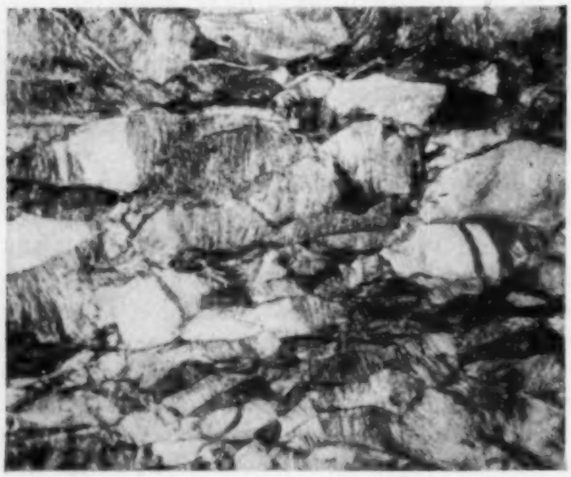
In alloys having more than one phase, the heating and rate of cooling determine the amount of each phase present. This is particularly important in the case of the precipitation hardening alloys such as beryllium copper.

Micrographs on this page are at magnification of 75 diameters.

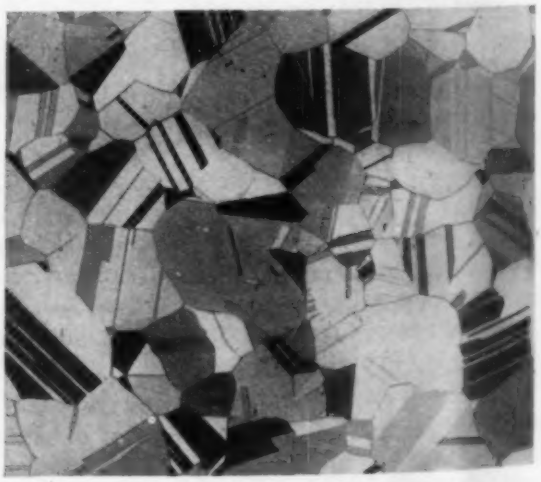
Commercial Bronze
Copper 90, Zinc 10
44% reduction by cold rolling



Commercial Bronze
Copper 90, Zinc 10
Annealed

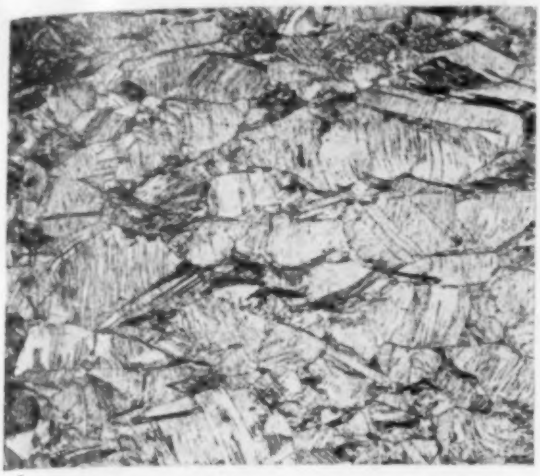


Cartridge Brass
Copper 70, Zinc 30
50% reduction by cold rolling

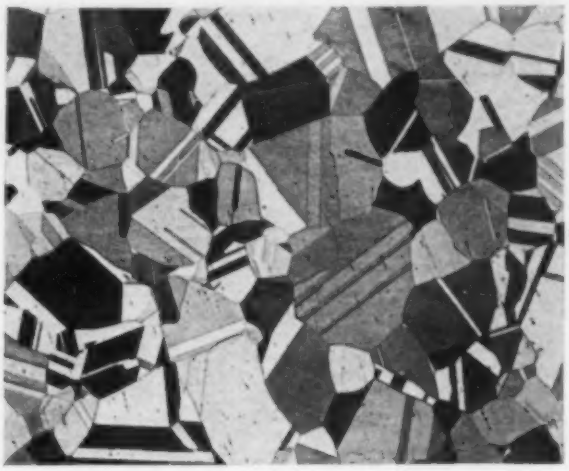


Cartridge Brass
Copper 70, Zinc 30
Annealed

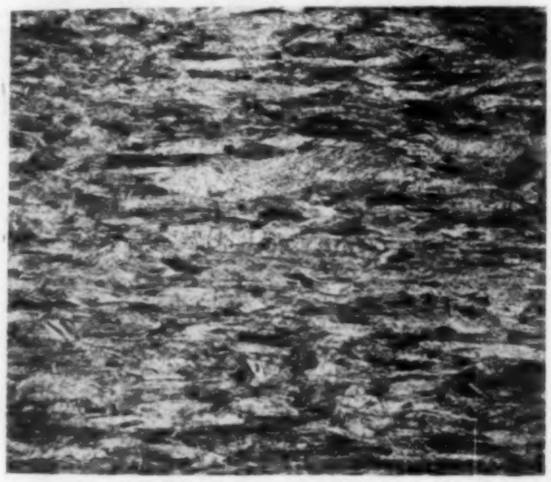
Micrographs of Copper-Base Alloys



Phosphor Bronze
Copper 92, Tin 8; Phosphorus present
50% reduction by cold rolling



Phosphor Bronze
Copper 92, Tin 8; Phosphorus present
Annealed



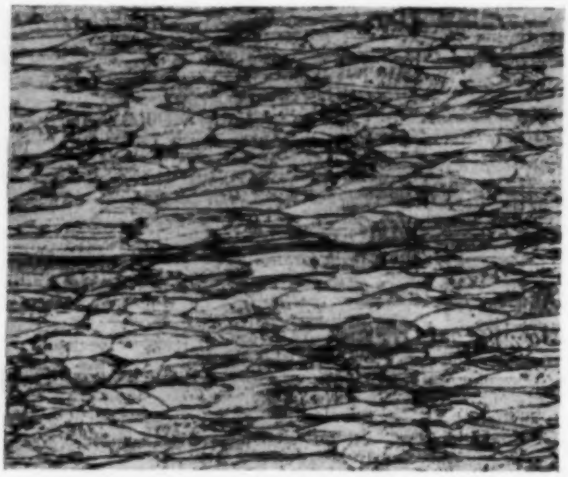
Aluminum Bronze
Copper 95, Aluminum 5
60% reduction by cold rolling

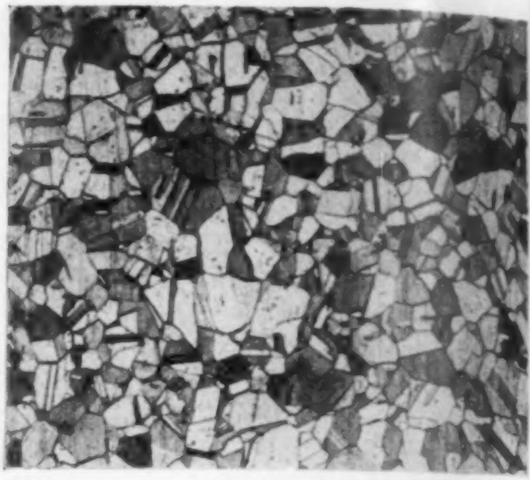
Aluminum Bronze
Copper 95, Aluminum 5
Annealed

Silicon Bronze (Everdur) Type A
Copper 96, Silicon 3, Manganese 1
50% reduction by cold rolling

Silicon Bronze (Everdur) Type A
Copper 96, Silicon 3, Manganese 1
Annealed

Magnification 75 Diameters



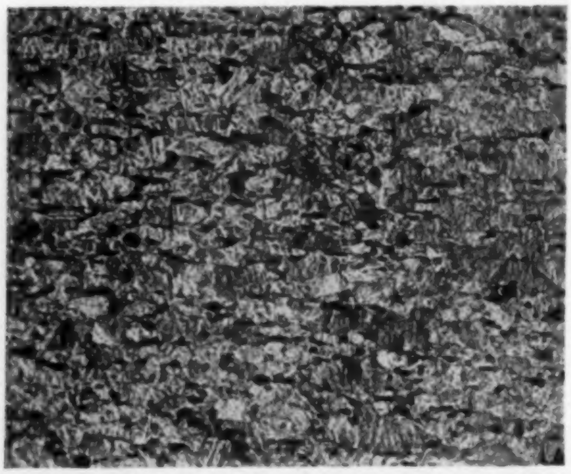


Tube cold drawn (150 diameters)

Cupro Nickel 30%

Copper 70, Nickel 30

Tube annealed (150 diameters)



Cold rolled, then precipitation hardened
(Beta phase etched to appear black)

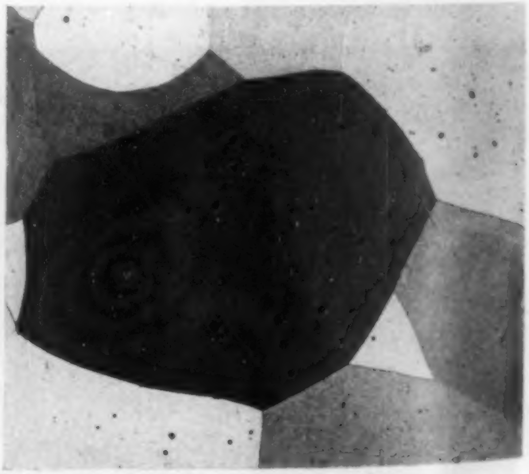
Beryllium Copper

Copper 97.50, Beryllium 2.15, Nickel 0.35

Annealed and quenched from 800°C.
(1470°F.) after cold rolling

Free Cutting Brass Rod

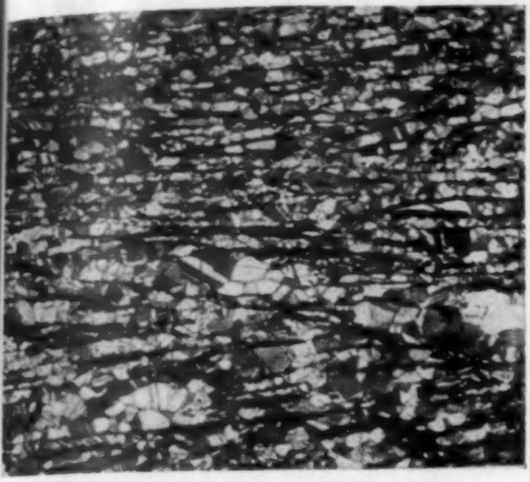
Copper 61.50, Lead 3.00, Zinc 35.50; Extruded hot, then cold drawn. (Beta appears as fine black streaks; lead is in rounded particles)



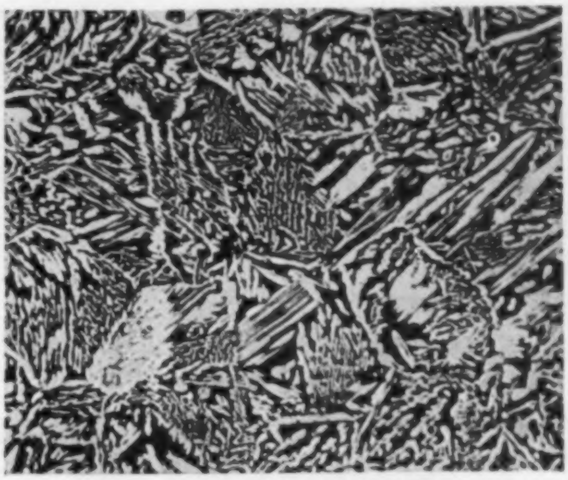
Brass (Spelter) Solder

Copper 52, Zinc 48
Grains entirely of beta phase
(Used in granular condition for brazing)

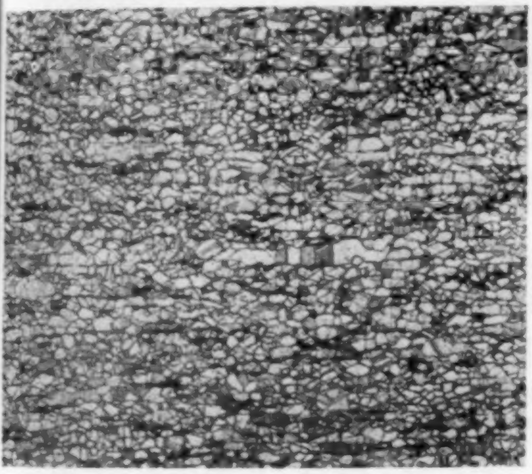
Magnification of Four Micrographs 75 Diameters



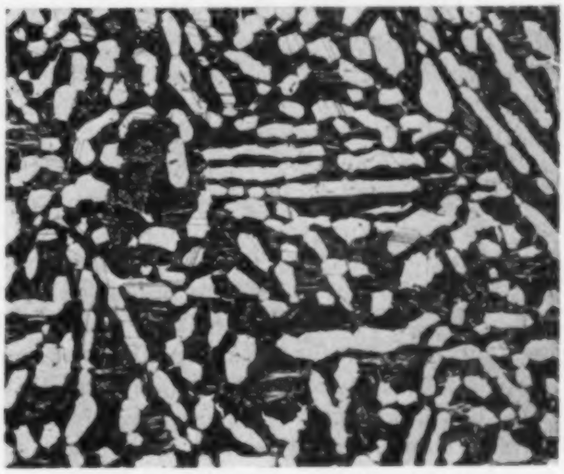
Hot Rolled Naval Brass (Tobin Bronze)
Copper 60.00, Zinc 39.25, Tin 0.75
(Alpha plus Beta structure)



Extruded Naval Brass
Copper 60.00, Zinc 39.25, Tin 0.75
(Beta grains with Alpha)

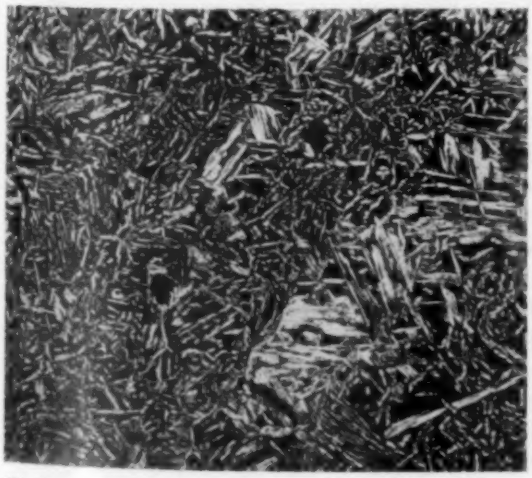


Extruded and drawn

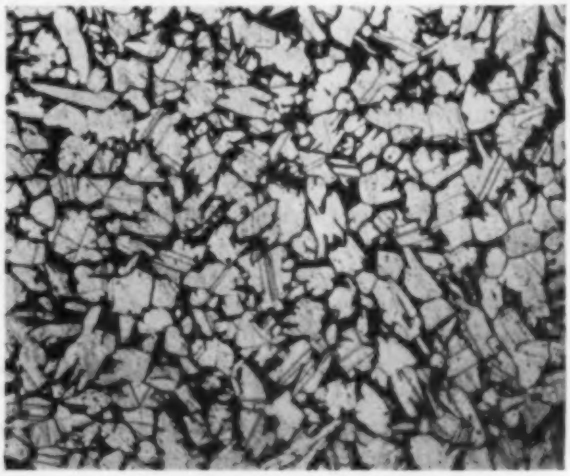


Annealed at 900°C. (1650°F.) and quenched in water

Aluminum Bronze (Avialite)
Copper 89.25, Aluminum 9.25, Tin 0.49, Iron 0.60, Nickel 0.59



Hot forged



Annealed at 900°C. (1650°F.) then cooled in air

Aluminum Bronze (Avialite)

The beta phase in the above micrographs is etched so as to appear black. Magnification 75 diameters.

Letters of Interest from Home and Abroad

Fast and Accurate Analytical Methods

BEVERLY, MASS.

To the Readers of METAL PROGRESS:

Although matters of strictly chemical interest are seldom found in *Metal Progress,* there are many of us who have a direct or supervisory interest in analytical methods for metals and alloys, and in labor saving and time saving methods therefor. Hence our interest in the photocolorimetric method for traces of bismuth in lead, briefly described in "Critical Points" for June.

Some readers may not know that this is one of several fast procedures now successfully used in metallurgical laboratories. The first instrument of this type is credited to Dr. Sheard and Dr. Sanford of the Mayo Clinic back in 1928, and a very useful equipment is manufactured by Central Scientific Co. under the trade name "Cenco-Sheard-Sanford Photelometer". With it come directions for 30 or more tests by selecting suitable filters for estimating intensity of colors found to be a measure of the element or compound sought. Molybdenum in steel, phosphorus in steel and several procedures used in chemical and biochemical laboratories are now, I think, very common. The colors of the comparison solutions in molybdenum tests are so permanent that measurements may be made with them at any time for several days after they are prepared, and no standard color solutions are needed when the galvanometer has once been calibrated. Details are given in a paper by George M. Poole, chief chemist of Ingersoll Steel & Disc, in *The Iron Age* for Oct. 9, 1941.

Equipment more in line with that described in "Critical Points" is the Coleman Universal Spectrophotometer (Wilkens-Anderson Co., Chicago), which selects a narrow band from an appropriate place in the continuous spectrum and measures the intensity of light transmitted by a solution of the unknown. Molybdenum, manganese, chromium, nickel, copper and phosphorus can be estimated in this way.

The spectrometer is now well known as a tool for quantitative chemical analysis. Rapid electromagnetic carbon determinators have been used in steel plants for many years. More accurate combustion carbons can be made in 3 min. by measuring the *volume* of CO_2 gas generated from the sample and absorbed in caustic. Sulphur analysis, which has been such a task for steel analysts, may now be made by combustion in 5 min. The SO_2 gas is converted into sulphuric acid, passed through a standard NaOH solution, and the excess alkali measured by titration. Equipments for these fast combustion methods are marketed by Harry W. Dietert Co. of Detroit.

I think it is a fact that not much progress has been made in the past few years toward improving and shortening some common laboratory tests such as silicon in cast iron or steel. I would be glad if I were mistaken as to this point. Some of the new methods also require expensive equipment not available for small output.

WALTER G. BULLARD

"Fish-Eyes" in Steel Welds

CLEVELAND, OHIO

To the Readers of METAL PROGRESS:

An interesting series of articles on the effect of hydrogen gas dissolved in steel has appeared in *Metal Progress,* written by Carl A. Zapffe, who quite obviously has given the matter unusually close and intelligent study. However, in the last article (March issue) he has blamed hydrogen for "fish-eyes" in steel welds, on what I think is quite insufficient evidence. That article also implies that moisture present in the coating or in a humid atmosphere has a markedly deleterious effect on the physical properties of the resultant weld with a coincident introduction of many "fish-eyes" as shown in the tensile fractures. This is contrary to experience with a very large number of tests made on welds over a period of years at the laboratory of The Lincoln Electric Co. To

A B C

D E F

Fracture of All-Weld-Metal Test Pieces, Made Under Following Conditions:

Duplicate Tests	Electrode		Coating Analysis *(a)*		Atmospheric Humidity *(b)*	Average Tensile Properities		
	Diameter	AWS Type	H_2O	Organic		Ultimate	Yield	Elongation
A	5/32	6010	1.00	2.53	3.4	70,200	54,200	23.5
B	5/32	6010	1.00	2.53	34.4	70,600	54,600	24.8
C	5/32	6010	0.73	2.53	3.4	72,100	56,800	22.5
D	3/16	6030	0.77	1.00	3.4	70,800	54,100	27.0
E	3/16	6030	0.77	1.00	34.4	69,300	53,900	27.0
F	5/32	6012	0.28	0.82	3.4	81,300	64,900	16.8

(a) Grams per 100 g. core rod consumed. *(b)* Grams moisture per cu.ft.

recheck the facts, the following tests were recently made and the resultant data are presented below the photograph of the fractures.

A represents American Welding Society's 6010 electrode with normal moisture content, welded in a dry atmosphere. *B* is the same electrode welded in a humid atmosphere. *C* shows the same electrode after drying to a moisture content somewhat below the normal range, welded in a dry atmosphere. *D* represents A.W.S. 6030 electrode with a normal moisture content welded in a dry atmosphere and *E* the same in a humid atmosphere. *F* represents A.W.S. 6012 electrode dried to a moisture content slightly below the normal range, welded in a dry atmosphere. It will be noted that in this last instance, the greatest number of "fish-eyes" accompanied the lowest moisture content and the lowest organic content (although such is not necessarily the case).

The dry air in these tests was ordinary unhumidified winter air in a heated room. The humid air was obtained by welding in a tank over boiling water.

From the table and attached photograph, it is evident that no correlation can be made between the occurrence of "fish-eyes" and *(a)* atmospheric humidity or *(b)* the moisture and organic material in the coating.

Other evidence which tends to weaken the hydrogen theory is that "fish-eyes" have been observed in a weld specimen ⅛ in. thick more

than ten years old which, according to Mr. Zapffe, is long enough to remove any effect of hydrogen. It also appears that welds made by the atomic hydrogen process, in an atmosphere of hydrogen, are free from "fish-eyes". Furthermore, we have not been able to corroborate Mr. Zapffe's results wherein he showed "fish-eyes" to be etched much more rapidly than the surrounding metal.

At any rate, it would be foolish to curtail welding operations during humid weather. To make a practice of drying electrode coatings below their normal moisture contents would be to invite trouble on certain types of welds.

So far, the criticism in this letter is destructive, and a fair question to ask would be "Well, if hydrogen is not to blame, what *is* the cause of 'fish-eyes'?"

Unfortunately, we are not able to advance any theory which will not be open to question. Henry & Claussen, in their book on "Welding Metallurgy", 1940, page 69, favor the following explanation:

"A curious combination of ductile and brittle fractures sometimes is observed in tensile bars of weld-metal deposited by organic covered electrodes. Around a tiny inclusion will be a zone of brittle failure, which in turn is surrounded by the ductile failure characteristic of the metal. It is thought that the inclusion concentrates stress in its vicinity, if, particularly, there are shrinkage stresses in the specimen."

"Fish-eyes" are by no means confined to welds made with "organic covered electrodes" and their focal point is much more often a void than an inclusion. However, the above explanation seems to us to fit the facts as well as any.

The facts as we see them are:

1. Failure must occur in tension to develop "fish-eyes".

2. The bright area represents a progressive fracture starting at the central defect.

3. Defects of a critical small size must be present. A larger defect (especially a smooth rounded one like a gas hole) is not likely to cause a "fish-eye".

4. The lower the inherent ductility of the metal (other things being equal), the greater the tendency for this type of fracture.

5. Thermal stress-relief prevents the formation of "fish-eyes" in subsequent testing. (Is this due to the relief of internal stress, the increase in ductility induced by tempering, or to the dissipation of trapped hydrogen?)

6. As far as we have been able to determine, the chemical composition, microstructure and hardness of this bright area are the same as that of the adjacent metal.

"Fish-eyes" have at times been confused with what some writers have called "auto-cracking" in welds. The latter are analogous to the formation of "flakes" in alloy steels, in that actual cracks are formed during cooling, and are caused by excessively high cooling rates such as are encountered when a small weld is made on a large mass of cold metal, or a weld is quenched in water from the welding heat.

"Auto-cracks" cannot be removed by heat treatment and do not have the characteristic "fish-eye" appearance. They are very serious defects and should be avoided by all means. "Fish-eyes", on the other hand, often occur in welds which are highly satisfactory in every respect. Some types of electrodes which normally produce a few "fish-eyes" in tensile specimens can, by abnormal welding technique, be made to deposit weld metal entirely free from them, although such a weld metal will have decidedly inferior physical properties.

It is our opinion that "fish-eyes" have been the object of undue anxiety and that in practically all cases, except possibly where fatigue is a primary factor, they could well be ignored.

PAUL E. JERABEK
Metallurgist
The Lincoln Electric Co.

Dr. Zapffe's Closure:

MR. JERABEK's arguments about the association of fish-eyes and dissolved hydrogen are mildly surprising at this date, since too many laboratories have verified the relationship set forth in my articles. His data record differences in the *availability* of hydrogen in the surrounding atmosphere, and nothing about the hydrogen absorbed by the metal under his welding conditions. The "hydrogen theory", by the way, does not demand that fish-eyes form in welds when hydrogen is present in the atmosphere at the time the weld is made, but that considerable hydrogen be present in the metal when fish-eyes form. The fish-eye is then the visual evidence of an accumulation of hydrogen around some discontinuity in the metal. One would judge that the welding conditions in all Mr. Jerabek's test pieces were such as to deposit metal somewhat less than sound and to absorb some hydrogen during deposition. Fish-eyes in weld metal tested 10 years after deposition and from which hydrogen has probably evaporated are explainable on the basis that the metal cracked internally early in its life when hydrogen was still present and while the metal was mechanically or thermally strained beyond its ability locally to resist.

Cartridge Brass Defects

Rome, N. Y.

To the Readers of Metal Progress:

Mr. George Foss brings up an interesting method of inspection (in the "Bits and Pieces" pages in July) for catching defects in brass disks prior to putting them into production.

As everyone knows, it is impossible to make articles which are 100% perfect and the brass industry is no different from any other. It therefore becomes necessary to inspect as carefully as possible all raw material for cartridge brass disks, and to inspect the disks themselves after blanking. It is usual practice to proportion punch and dies so the blank is actually *cut* for a relatively short distance, and the remainder of the thickness is broken. This type of edge tends to show internal defects quite clearly and, in principle, is applied to extruded rods of all alloys to detect and eliminate "extrusion core."

All disks made by Revere are 100% inspected on surface and edge for defects which will cause defective cases or which will be troublesome in the fabrication. Even so, a normal rejection of 1% on blank disks for laminations and similar internal defects is expected. If this increases to 5% or more, an immediate investigation is started in the mill as to cause. (This 5%, incidentally, is applied to small lots and not large ones.)

There is always a question of judgment as to whether very small defects, such as porosity or small laminations, will cause difficulty in the drawing operations at a customer's plant. A test run was made recently on 700 pieces with laminations which were only ⅛ in. long and very shallow. As a matter of fact, there was a difference of opinion between inspectors as to whether or not this material would or would not work satisfactorily. The entire lot was processed with very close supervision and the final check showed that the percentage of defects in the finished case was no different from the average run of material with absolutely sound edges.

It's interesting to note that two customers who received a very large amount of this material reconditioned about 1% of the cases due to defective metal. In one of these plants there were only 454 totally scrapped cases in the first million manufactured — which is indeed a satisfactory percentage.

It seems probable that it is impossible to avoid a certain amount of repair work, especially since our experience is that defects in finished cases can be produced during the drawing operations if the punches or dies in the initial cupping and drawing operations are allowed to "brass up" or are otherwise fouled. If deep scratches are produced in the cupping operation, these can later result in discards for small slivers and laps at the finish inspection.

The whole point is that defects found in finished cases are not all due to faulty metal, and that it would seem that there always will be some material which cannot be caught by any manner of inspection under present methods, no matter how careful.

I would like to point out also that inspection of incoming metal at case manufacturers' plants will necessarily vary as to size of lots. If material is made at a modern mill where heat numbers can be and are segregated, it is far easier to segregate and inspect in the shell case plant. If casting lots are small at the fabricator's plant and actual heat numbers are not identified, then an inspection procedure at a customer's plant will only show average results, and not be able to spot an individual lot.

Carl O. Windrath
Supervisor of Methods, Rome Division
Revere Copper and Brass, Inc.

Data on Damping Capacity of Many Metals Now Available

Sheffield, England

To the Readers of Metal Progress:

Although much has been written during the last few years regarding the importance of damping in connection with many engineering uses of steels and other metals, no great amount of data concerning the actual damping capacities of different metals — particularly of different steels — can be found among the various publications. For that reason a paper on "Damping Capacity and Engineering Materials", presented by Hatfield, Stanfield and Rotherham to the North East Coast Institution of Engineers and Shipbuilders, Newcastle (England) in May, should arouse considerable interest among both engineers and metallurgists. Its main purpose is to provide detailed information hitherto lacking.

Dr. Hatfield and his colleagues determined damping characteristics by measuring the rate of decay in the amplitude of torsional vibrations and, for this purpose, they designed an instrument which is noteworthy in that it appears to be free from certain sources of error to which earlier instruments, constructed for the same purpose, have been subject. In some of these earlier instruments the error had been so serious as to make the results obtained of doubtful value.

Using this new instrument, they have determined damping characteristics of 30 different

steels (including many high alloy steels), 11 cast irons, 21 other metals and alloys and such other substances as sintered carbide, glass, ivory, ivorine and bakelite. Values have been obtained for each material at different stresses and, in the case of the steels and three other metals and alloys, at temperatures up to 900° F., or even higher in a few instances. The whole constitutes a mine of information to which those concerned with the effects of damping in engineering practice will doubtless refer for a considerable time.

A survey of all these data brings out some interesting facts: In the first place, certain general ideas which have gained currency during the last few years are confirmed. Thus, lead and cast iron both exhibit high damping, lead giving 20 to 30% damping per cycle, depending on the stress. The results from different samples of cast iron varied appreciably. Values at 2000 psi. ranged from 6.24 to 16.0% damping per cycle. It appears that although damping capacity in this material increases with graphite content, it is also affected by small differences in casting conditions, and probably by other factors.

The values obtained from mild steel were greater than those from higher carbon steels or low alloy steels — again confirming ideas previously held. Seven different samples of bakelite were tested, and all gave high values, of the same order as those given by lead; ivory gave values about half those from bakelite.

On the other hand, many peculiarities were found: Thus, two samples of mild steel, differing only slightly in composition and mechanical properties, gave markedly different damping values at atmospheric temperature, and these values were not affected in the same way by raising the temperature.

Stainless steel containing 13% chromium exhibited, on the average, considerable damping capacity — an interesting fact in relation to the widespread use of this material for turbine blading — but some large and puzzling differences were noted between the values obtained from the half-dozen different specimens of this material which were tested. Thus at atmospheric temperature the damping per cycle at 4500 psi. varied between 0.88% and 8.0%.

On the other hand, austenitic chromium-nickel steels — whether of the 18% Cr, 8% Ni; 25% Cr, 20% Ni; or 12% Cr, 36% Ni types — rather surprisingly gave uniformly low values; the figures under the same conditions as those for stainless steel, mentioned in the paragraph immediately above, varied between 0.3 and 0.66%, values of the same order as were obtained from high tensile, low alloy steels.

Further investigation will no doubt elucidate the causes of these and other differences shown by various samples of seemingly similar material, but meanwhile the paper records a mass of interesting and valuable data.

J. H. G. Monypenny
Metallurgist
Brown, Bayley's Steel Works, Ltd.

No New Copper or Tin Going Into Railroad Bearings

Washington, D. C.

To the Readers of Metal Progress:

Late in 1941 the Advisory Committee on Metals and Minerals presented a report to the Office of Production Management (predecessor of the War Production Board) on the proper use of our short supply of copper, both primary and secondary. The O.P.M. shortly thereafter urged the Association of American Railroads (A.A.R.) to do everything possible to reduce its requirements by every possible means. Tin was added to the list of scarce metals some time later.

The Association appointed in January, 1942, a committee designated as the Committee on Journal Bearing Development and an extensive program of testing and development of car journal bearings was immediately instituted. This program has involved the continuous use of the testing laboratory of the Railroad Service & Supply Co. at Indianapolis, which was taken over on a full time basis by the A.A.R. under continuous supervision of a resident committee. Laboratory procedures were set up designed to demonstrate, as far as laboratory tests can, the suitability of car journal bearings for railroad service. The entire committee has met at frequent intervals with the resident group in order to study results already developed and to lay out the program for future work, and has investigated a large number of variables in design and in materials. The entire aim of the work has been to conserve copper and tin, and the results have been appraised entirely on that basis.

At the very beginning of this work the Committee redesigned the standard A.A.R. journal bearing by reducing dimensions. [See *Metal Progress*, August 1942, page 223.] This work was accomplished in two steps, the first during January 1942 and the second during May 1942, and all journal bearings are now being manufactured to these cut-down dimensions, which have been issued as A.A.R. standards. This has resulted in the manufacture of five of the wartime emergency bearings from the material received in four worn out pre-war bearings. In view of the fact

that car ownership has not been increasing appreciably, there has resulted a gradual building up of a surplus of journal bearing metals resulting from the conversion, through re-melting and re-manufacture, of the pre-war design to the emergency design. At the present time, it is the understanding that approximately 15,000,000 lb. of such surplus journal bearing metal is in the hands of the bearing manufacturers. [This general situation was described by E. S. Pearce in *Metal Progress* for September 1942, page 368.]

The Committee has been in close touch with the Conservation Division of the War Production Board and has been informed that there are no other approved uses for this surplus except the manufacture of A.A.R. journal bearings. Inasmuch as the average life of a car journal bearing has been approximately four years and even under the present intensive use of cars incident to wartime traffic, is probably more than two years, this stock pile of surplus bearing metal will continue to increase for at least two years or perhaps longer. By drawing on this to make up for foundry losses and metal actually worn away in service, it seems likely that the railroad bearing industry could subsist without the necessity of purchasing new metal for four or five years, assuming that the stock pile of surplus is left in the hands of the railroads and the railroad bearing manufacturers. This means that as far as purchase of copper and tin for use in journal bearings is concerned, the changes already made and now in effect have resulted in a saving of 100% of the copper and tin requirements as compared with pre-war practices. Thus, the railroads have not only reduced their requirements for these metals in accordance with conservation orders of the W.P.B., but have entirely eliminated them for the time being — and probably for several years in the future.

In order that the railroads might be in a position to continue to operate efficiently in the event the War Production Board finds it necessary to divert the present surplus to other uses, the Committee has worked intensively toward the development of other bearing metals or designs which would still further reduce the requirements for tin and copper. Out of a large group, the Committee has selected the so-called "V Bearing" as the design which to date offers the maximum of conservation, combined with the laboratory indications of satisfactory service performance. This bearing consists of a malleable iron adapter or back which is substituted for a large portion of the bronze back now used in the A.A.R. design, this adapter being lined with a thin bronze insert with standard soft white metal facing to contact the journal of the axle. This bearing uses only one-third as much bronze as the present wartime design A.A.R. bearing. In view of the surplus accumulation already described, it is obvious that the immediate adoption of the "V Bearing" as an A.A.R. standard or alternate standard offers no further economy in the use of copper and tin, but the Journal Bearing Committee has felt, in view of the possibility that uses may be developed for the present surplus, that an extensive service test is extremely desirable, so it could be in a position to know definitely if this bearing would be satisfactory in general service if necessary. The General Committee, which has final authority in such matters, has therefore arranged for the experimental installation in regular service of some thousands of the "V Bearings" to be applied to car equipment of approximately 20 railroads. Through this service test the Association will be in position to act promptly and without the delay incident to research in the event it should become necessary to divert a substantial quantity of journal bearing metal to the use of other industries. To be conclusive this service test should be continued for at least one year and possibly longer.

C. H. Buford
Vice-President, Association of American Railroads
Operations and Maintenance Dept.

Martensite and Superstructures

Somewhere in France★

To the Readers of Metal Progress:

In the May Lecture of the British Institute of Metals in 1933, I showed the similarity between the quenching phenomena in steels and in light alloys, and at the same time pointed out that in light alloys the intermediate state between high temperature equilibrium (solid solution) and equilibrium after cooling (aggregate of two phases) had not yet been clearly observed under the microscope, although it did exist in steels as the martensitic structure.

I regard the martensitic state in steels as partaking of the high temperature equilibrium, since martensite is a solid solution like austenite. It also partakes of the room temperature equilibrium, since the crystalline network of martensite is very like that of ferrite. The dispersion is therefore atomic or molecular. (This martensite corresponds to the maximum hardness attainable by quenching alone.)

★This letter is one of a group received some time ago, much delayed in transit, and mailed from "Free France" immediately before the occupation by German troops.

At that time no similar analogies had been noted for the light alloys; this has since been done, thanks to more recent spectro-radiographic studies on quenched light alloys:

1. Studies by Wassermann, by Preston and by Guinier on aluminum-copper alloys show that the precipitation associated with approach to equilibrium on cooling is preceded by the segregation of copper atoms in preferred crystallographic planes (001). This is a characteristic aspect of the heterogeneity preceding precipitation to which I believe (along with Chevenard) the hardening of these alloys is related.

2. Even more definitive studies by Fink and Smith and by Chaudron and Lacombe on aluminum-magnesium alloys demonstrated the appearance of superstructure lattices preceding precipitation. These superstructures would be the equivalent of martensite in steel.

Particularly in the aluminum-magnesium-zinc alloys studied by Chaudron and Lacombe, the formation of this intermediate phase (which follows a definite pattern with regular atomic distribution) is alone responsible for the widest variety of mechanical properties on transformation of the phase stable at high temperature. It is similar to martensite, the intermediate phase in steels, which is the origin of the maximum hardening by transformation of austenite.

The analogy is striking and clears away the disparity we had noted between the light alloys and steels, although in the case of martensite in steel we cannot actually speak of structure since it is more a question of interstitial solid solutions in which the distribution of the small carbon atoms is poorly defined by spectro-radiography. (See, for instance, the recent researches by Petch of Cambridge University — METAL PROGRESS for May 1943, page 762.)

It would seem that in their search for equilibrium at room temperature the atoms first attempt to achieve a temporary location requiring the least movement, before adopting their ultimate position; they abandon their initial condition with difficulty, searching first an accommodation or compromise between this condition and their new, final and normal condition of equilibrium.

These studies do not yet cover the general field of light alloys, and enough results have not yet been accumulated to follow in detail the comparison with steels. For instance, it should not be affirmed that in all cases the intermediate condition is a necessary stage in the transformation leading to the room temperature equilibrium or annealed condition. Nor can it be definitely said that this phase is a step in the transformation that can be dispensed with under certain circumstances, even though it seems to be possible to short-circuit it and pass from austenite to the ferrite plus cementite aggregate by transformation at constant temperatures above A_r'', where martensite normally would form.

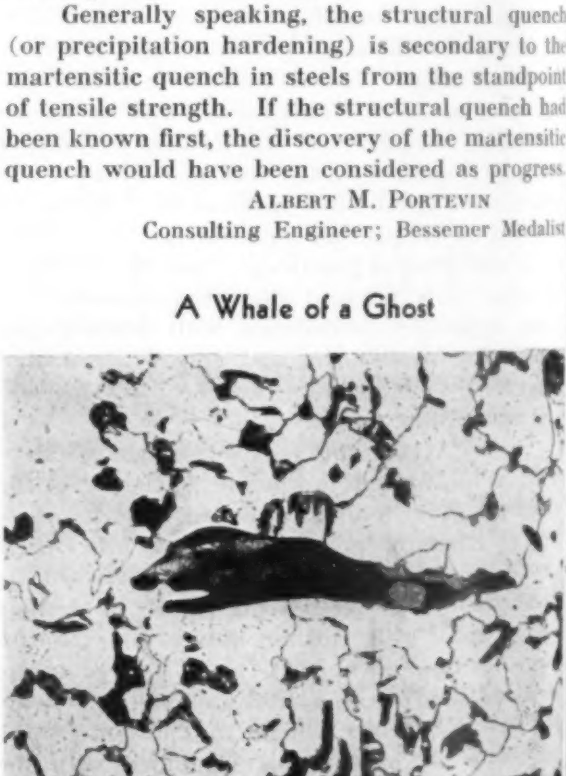
From the standpoint of mechanical properties it is interesting to note, however, that in steels as well as in the light alloys, the best relationship of tensile strength to ductility (measured as elongation in the tensile test) or impact (notched-bar) strength is obtained by passing through this intermediate stage. Thus, the aluminum-magnesium-zinc alloys can attain tensile strengths of 125,000 to 135,000 psi. with 15 to 10% elongation, which is in the neighborhood of a semi-medium steel, as rolled. This "light" alloy, however has a density of only 2.81 (vs. 7.85 for steel).

Hardening by precipitation, or structural quenching, is a widespread phenomenon applied with interesting and useful results to a large number of alloys. It even applies to the martensitic hardening of steel, in that it may be regarded as the reason for the supplementary hardening which occurs at the very beginning of tempering of martensite.

Generally speaking, the structural quench (or precipitation hardening) is secondary to the martensitic quench in steels from the standpoint of tensile strength. If the structural quench had been known first, the discovery of the martensitic quench would have been considered as progress.

ALBERT M. PORTEVIN
Consulting Engineer; Bessemer Medalist

A Whale of a Ghost



In Sea Faring Steel, Found by
LOUIS A. NOWELL, JR.
Metallurgical Dept.
U. S. Naval Engineering Experiment Station

Furnaces and Atmospheres

Wartime Applications of Industrial Gas Equipment

By E. G. de Coriolis
Research Director, Surface Combustion, Toledo, Ohio

SPEAKING on the subject "Industrial Gas Equipment of the War and Post-War Periods" at the spring meeting of the Industrial and Commercial Gas Section of the American Gas Association, Mr. de Coriolis recalled the situation which existed 20 years ago when the Section was organized. Faced with the necessity for increased sales of industrial gas, to replace the dwindling domestic consumption, the Association realized that adequate equipment must first be developed. "Fuel and equipment had to be presented in a combination capable of producing a result acceptable to industry. There was but one way of reaching the goal: It had to be along the path of research." Research developed the method of burning gas by diffusion combustion, the indirect product known as the radiant tube, the controlled atmosphere, and adequate machines for heating by the convection principle. Each of these has had special developments applying to war products. Quotations from Mr. de Coriolis' paper now follow:

Forging Furnaces — Equipment during the first European War was sadly lacking. In one instance, a manufacturing plant on war production secured permission to close off a city street by throwing a shed over it. Beneath the pavement was a gas main. Outlets were run into improvised forge furnaces and gas went to work. When the war ended the shed was torn down, the forges discarded and the street restored to its former use. Gas had done its job as an emergency fuel but for peacetime forging fuel oil remained the preferred fuel.

Since gas had done such a good job as an emergency fuel, one of the first attempts to apply the newly discovered process of diffusion combustion was to forge furnaces. (This process — described first in *Metal Progress*, Sept., 1932 — comprises laminating the flow of streams of fuel gas and air in the proper proportion for complete combustion while maintaining these fluids within an enclosure in a non-turbulent stream. When so maintained, there is no admixture of the gas with the air but instead combustion proceeds by interdiffusion and is maintained at the boundaries of the respective streams. A by-product of this method of combustion is that the hydrocarbons in fuel gas are cracked, with the evolution of carbon clouds which become highly luminous and radiant, and capable of very rapid heating.)

Diffusion combustion as such did not prove successful in forges, for the furnaces had to be closed and the work had to be quite uniform in section and present no obstruction to the path of the flames. Otherwise the flames were "spilled", that is, the streams were broken, turbulence set in. However, when gases were so burned by partial diffusion the scale was no longer thin and tenacious, but heavier and quite loose, a characteristic highly important for successful forging.

Applications of this type are now rendering very effective service in forging billets for high explosive shells. As it comes from the furnace the billet is passed through a scale breaker and the quality of heating is judged by the ease and completeness with which the scale is removed. After extrusion or pressing the rough shell is examined for imbedded scale, and if conditions are not properly maintained, rejections by inspectors mount up rapidly, for these shells receive no cleaning before they enter the machine shop.

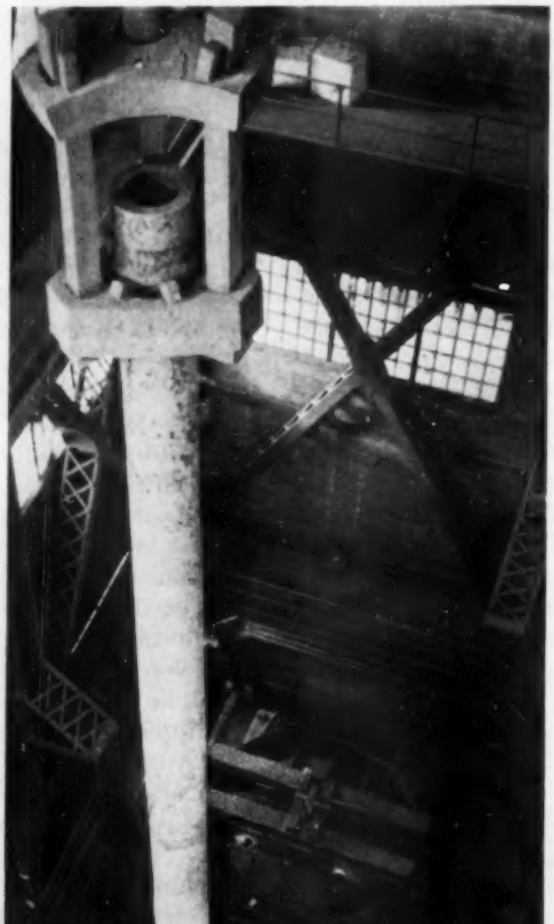
A type of furnace embodying this application is a rotary hearth furnace with several burners firing along its periphery, each with a device by which the flame can be varied from premixed to luminous while maintaining the same proportions of air to gas. In addition, the furnace is equipped with automatic damper control to exclude air intrusion even with frequent openings of the charge and discharge doors. There are also two zones of temperature control which are adjusted

so that a blanket of flame is held over the work in the discharge zone.

This is a far cry from the forging operation previously described during the European War when a gas pipe was pushed up through the street pavement into a pile of brick, and expected to do a job.

Radiant Tubes, often described in recent technical literature, are an indirect product of the research into diffusion combustion. Gas burned under pressure in a tube was far from satisfactory. Under diffusion combustion the air and gas were separated; the gas flowed freely into the tube, and the air drawn in simply by placing the tube under suction. This scheme accomplished several results:

It immediately simplified the introduction of air and gas in non-turbulent flow. It facilitated ignition by having the entering end of the gas stream readily accessible. Since combustion proceeded progressively it made possible greater flows of gas, thus increasing heat output. By streamlining the flame hot spots were eliminated and a greater temperature uniformity throughout the length of the tube was achieved. And finally, by having the combustible and air under negative pressure throughout the tube length it insured that, in the course of time as cracks would begin to develop in the tube wall, no outward leakage of flue gases could occur. But above all else, and what guaranteed long life of the metallic tube, was the fact that the air stream was maintained at the tube wall while the burning gas was held in the center, away from the tube surface, and imparted its heat to the wall mainly by radiation. It also opened up the entire field of controlled gas atmospheres for carburizing, and for heating before quenching in a protective atmosphere, by keeping the products of combustion entirely separate from the work without the necessity of expensive retorts or muffles.



Crane-Man's View of Big Gun Tube, Withdrawn From Heating Furnace, Ready for Quench in Deep Tank of Oil (Lower Right Corner). Courtesy Bethlehem Steel Co.

Prepared Atmosphere Quench — Many hours could be spent in describing the considerable number of war applications in which the combination of radiant tubes and prepared atmospheres is playing an important part. One deserves special mention. It is the prepared atmosphere quench:

In the heat treatment of seamless tubes it had been the practice to anneal in direct-fired furnaces followed by pickling. As the tubes became smaller in diameter, controlled atmosphere furnace would be used in order to control the character of the metal surface for subsequent drawing. When finished to size, the tubes were usually freed from drawing compound and bright normalized in radiant tube roller hearth furnaces with elongated cooling zones. Seamless tubes becoming an important component of aircraft with close metallurgical specifications, it was necessary to quicken the cooling rate. This was achieved by a fan to agitate the atmosphere within the cooling zone.

More recently, new methods have produced the tubing by welding from a strip. This type is much more difficult to heat treat and it was necessary to develop a radically different method of cooling. Powerful fans, one above and one below the level of the roller conveyor in the cooling

(Continued on page 654)

Wartime Furnaces

(Continued from page 648)
zone, now circulate the prepared atmosphere through refrigerator coils, and the cold atmosphere strikes the tubes, top and bottom, at cyclonic speeds, resulting in a veritable quench. About 50% of the heat imparted into the tube as it travels through 55 ft. of furnace is absorbed by the atmosphere in the first 4 ft. of the quenching zone. In terms of time this is equivalent to reducing the tube temperature down to black heat in 30 sec. Meanwhile, since the furnace inlet and the cooling zone outlet are open to allow for constant ingress and egress of the tubing, it is necessary to balance this internal cyclone so delicately that air does not intrude at either end, while the flow of atmosphere gas exudes and burns with a steady blue flame.

By controlling this "gaseous quench" the physicals of the treated tubes may be made to conform to exact aircraft specifications.

Growth of Convection Heat — Another field in which industrial gas has played an important part is in the utilizations of the forced convection furnace. The air-draw furnace of the tool room and small production shop has been a familiar piece of equipment for several years. But the application of convection heating on a large scale has been almost wholly a war development. Generally one is inclined to limit refinements in heat treating to the tool room and automotive plants. In more recent years the non-ferrous industry (copper, brass and aluminum) has made increasing use of convection heating for its various processes, particularly for close control of grain size.

But it remained for the present war effort to demonstrate its effectiveness in the heat treatment of armor plate. Here is an ancient art which had depended solely upon human skill in performing a heating operation fully as delicate as that of any tool room process. Plates over 30 ft. in length and weighing a great many tons have to be heated at temperatures which differ from one end to the other, due to variable composition of the steel which cannot be made absolutely uniform lengthwise. Differences of 10° F. have to be within the control of the operator.

Heretofore this had been attempted by having a great many thermocouples welded to the underside of the plates and firing overhead by hand controlled burners. Only a single plate could be heated at a time, although in terms of capacity these furnaces could have held many times the tonnage. The adoption of convection heating has revolutionized this process. Plates are now heat treated accurately, still maintaining a different temperature from one end to the other. Control is accomplished by predetermined and automatic means, as directed from the laboratory. Of no less importance from a production viewpoint is that several plates of analogous chemical variation can now be charged simultaneously, thus considerably increasing tonnage output. (*Cont. on p. 656*)

(Starts on page 647)

Accuracy of heat treatment can be further illustrated by the notable performance of furnaces for high explosive shell, developed at Frankford Arsenal and described in detail by Colonel Bomar in *Metal Progress* for October 1941. The effort was to develop a furnace that, in an emergency, could be installed in shops unaccustomed to refined heat treatments. All the component parts, heating, quenching, tempering, operated as a single mechanism. When the crucial test came this highly refined, gas-fired equipment more than vindicated the arsenal's foresight. After shell manufacturing plants had already got into wartime production, it was found necessary to change the steel, and made it mandatory to heat treat all shell. This equipment was ready to perform. It carried into those plants, which heretofore had had no experience in the heat treatment of shell, the same degree of accuracy which had been developed by the arsenal during the previous peacetime period.

When convection heating was applied to the tempering step considerable further improvement resulted. The complete operation of hardening, quenching and tempering was also greatly facilitated by the adoption of the alloy walking beam in both furnaces and the mechanized internal quench tied in with the motion of the beams. All these refinements brought about "unit heat treatment", in the sense that the flow of shell could be varied from full furnace to practically no flow without affecting the quality of any shell going through. This peacetime development therefore became of extreme importance when it was decided to swing the total production to full heat treated shell. Many plants that had had no previous experience in heat treatment were able to enter into production of this type of shell, and achieve a notable record of performance, due to the reliability and consistency of the method and equipment provided for them by this peacetime development.

A great many other examples could be cited to show the active part that industrial gas has played in the war effort, but enough has been said to emphasize the desirability and economy of gas as a fuel, when handled in well designed equipment.